A DATABASE OF SYSTEMS MANAGEMENT CASES

THESIS

Julian R. Roberts, Jr., Captain, USAF

AFIT/GSM/LSY/90S-22

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GSM/LSY/90S-22

A DATABASE OF SYSTEMS MANAGEMENT CASES

THESIS

Julian R. Roberts, Jr., Captain, USAF

AFIT/GSM/LSY/90S-22

The opinions and conclusions in this paper are those of the author and are not intended to represent the official position of the DOD, USAF, or any other government agency.

AFIT/GSM/LSY/90S-22

A DATABASE OF SYSTEMS MANAGEMENT CASES

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Systems Management

Julian R. Roberts, Jr., B.S.

Captain, USAF

September 1990

Acknowledgements

I wish to express my sincere appreciation to all those who helped me complete this project. First, I would like to thank my thesis advisor, Lt Col Curtis R. Cook, whose experience with the case teaching method and case research techniques were instrumental in the successful completion of this research effort.

Special thanks go to Capt Fredric J. Weishoff II, AFIT/LSG, Capt Jeffrey D. Hearrell, ASD/ENSSE, and Lt Col Floyd G. Hemmig, ASD/VC, whose experiences were the bases for the cases written as a result of this research.

Finally, a special note of gratitude goes to my wife, Tracy, and our son, Brett, for their love, support, and understanding throughout the project.

Captain Julian R. Roberts, Jr.

Table of Contents

List of Figures

Page

List of Tables

Abstract

The purpose of this study was to generate a collection of systems management cases that would help graduate students and others learn the nuances of managing complexity. The cases will help ensure the systems management case database is up-to-date, and reflects current technology, theory, and management thought.

The research was based on a case writing methodology espoused by Leenders and Erskine in their book entitled Case Research: The Case Writing Process. Three comprehensive new cases were created: "The Vanguard Strategic Planning Process," which addresses issues concerning strategic planning in the Air Force; "The Analytic Hierarchy Process (AHP)," which describes a quantitative decision-making tool called the AHP and how it can be applied; and "Ground-Launched Cruise Missile (GLCM) Requirements," which describes how and why the GLCM system was acquired and how system requirements problems were addressed.

A DATABASE OF SYSTEMS MANAGEMENT CASES

I. Introduction

General Issue

Because of the increasing complexity of Department of Defense (DOD) weapon systems, the systems approach has become a preferred method of managing both research and development (R&D) and acquisition programs. Because of the prevalence of the systems approach, many universities, including the Air Force Institute of Technology (AFIT), have created graduate systems management programs. The case teaching method, which is widely accepted as an effective way for students to learn from the experiences of others (20:17), is particularly useful in the study of systems management. To insure the effectiveness of the case method in any field, the database of cases must be maintained in an up-to-date state, reflecting the use of current technology, theory, and management thought.

Specific Problem

A collection of current, military-unique case studies would be an extremely valuable learning tool for not only Air Force systems management students, but also other military and civilian students. Few such cases are currently available. The objective of this research is to

generate a collection of case studies that will expose systems management students to actual situations experienced by other system managers. These cases will provide students with the "applied" education necessary to complement the theoretical approaches they learn in other coursework.

Investigative Questions

The following group of investigative questions is intended to act as a guide in accomplishing the research objective. The documented cases resulting from this study will address these questions.

1. What important issues are involved in the strategic planning process for weapon systems?
2. What qualitative and quantitative methods of problem analysis and decision making are appropriate in managing weapon system programs?
3. How are weapon system functional and physical requirements identified and evaluated?

Organization of the Thesis

This first chapter discussed the need for current, military-unique cases to be used as teaching tools in systems management courses. Chapter II provides a review of literature applicable to the case teaching method and its effectiveness. Chapter III then describes the methodology used to generate cases. Chapter IV contains the cases produced from the actual case research, and Chapter V summarizes the results of the entire research effort and provides recommendations for further research.

II. Literature Review

Introduction

This review discusses two main topics related to the case teaching method. First definitions for the case and the case method are provided. Then, a series of sources that addresses the effectiveness of the case teaching method is reviewed. These sources discuss both pros and cons of the case method.

The Case Method

A case, in the context of this research, is a description of a management decision or problem faced by a real person, group, or organization. The case should contain "the relevant facts of the situation at the time the decision needed to be made or the problem existed" (17:10).

"The case method refers to the use of cases as educational vehicles to give students an opportunity to put themselves in the decision maker's or problem solver's shoes" (17:10). O'Dell describes the case method as a

> discussion of a case, typically a record of a business issue which actually has been faced by business executives, together with surrounding facts, opinions, and prejudices upon which the executives had to depend. These real and particularized cases are presented to students for considered analysis, open discussion, and final decision as to the type of action which should be taken. (20:17)

The case method has been used in both the legal and medical fields for many years but its use in the management field is relatively new. The Harvard Business School is

well-known for its role in developing the case method for management study (17:13). Since the 1920's, when this early development took place, various authors have written quite extensively on several issues concerning the use of the case method in management education. These issues include case writing, specific teaching methods, and the effectiveness or ineffectiveness of the method (9:116). The remainder of this literature review focuses on the case method effectiveness issue.

Effectiveness of the Case Teaching Method. In his Winter 1975-76 article from Collegiate News and Views, William F. O'Dell begins by stating "The fact that it continues to prosper despite many attacks is evidence that the case approach is, in fact, a sound teaching method." (20:17). According to O'Dell, the goal of the case method "centers around the development of independent constructive thinking on the part of the student" (20:17). Using the case method, an instructor pursues this goal by first discussing "the *possibilities* of combinations of intricate facts, the *probabilities* of human reactions, and the *expedients* most likely to bring about the responses in others that lead to a definite end" (20:17), and secondly by "opening free channels of communications between students and students and between students and teachers," thereby "achieving student participation" (20:17).

O'Dell then discusses the extreme views of the "case enthusiasts" who treat the "lecture method" and "case

method" as separate and distinct theories (20:17). Further, they see the lecture method as "comparable to a history course in which the student is asked to listen, read, and memorize" (20:17). On the other hand, the case enthusiast sees the case method as training students not to know but how to act (20:17). "It [case method] is concerned with precedents only so far as they lead to initiatives" (20:17). In addition, the case method "deals with the oncoming new in human experience rather than with the departing old" and "the student becomes an active participant rather than a passive listener" (20:17). According to O'Dell, most teachers using the case method fortunately do not take these extremist views and realize that there can be "a blending of the two theories of education drawing on the better parts of each" (20:17). O'Dell points out that

> to throw a student into a case discussion without adequate knowledge of the practices and techniques of a particular business function or discipline is not only unfair to the student but results in wandering discussions and inefficient use of the students' and professor's time. (20:18)

In addition, if an ill-prepared student is forced into a case discussion, the learning experience is diminished. For these reasons, most business teachers agree that the case and lecture methods are not mutually exclusive and the two methods should be used together (20:18).

O'Dell also discusses some of the weaknesses of the case method. First, students will sometimes use their time inefficiently during case discussions because of an open-

ended initial question from the instructor. Attempting to answer the question, students will often proceed in the "wrong" direction. Such a diversion is often led by "highly verbose and aggressive students" and will usually continue unless the instructor interrupts (20:19). Other potential weaknesses include a tendency for students to resort to superficial thought or "flying by the seat of their pants" and the lack of discussion contributions from reserved but otherwise competent students (20:19). O'Dell also cites students' lack of understanding of the decision-making process as a major cause of their loss of direction in case analysis. O'Dell's concluding point is that "the case method can be strengthened if more time is devoted to a vigorous student understanding of the scientific analysis of decision making" (20:21).

In his article from the September-October 1987 issue of Interfaces, Franz Bocker defines two classifications for cases according to the way they are used. Some instructors "use cases to liven up their teaching" (8:65); they "try to illustrate facts or procedures taught through a deductive teaching process with demonstration cases" (8:65). This teaching process is deductive because the teacher begins with general rules from which specific recommendations are derived (8:65). In the second use of cases, instructors "use cases as the foundation of an integrated inductively driven teaching process" (8:65). In this process, students

are asked to develop general rules of problem solving from specific problem-handling experiences (8:65).

Throughout the article, Bocker refers to the first classification as "demonstration cases" and the second as "problem cases" (8:65). Bocker's study focused on the effectiveness of problem case teaching. The goal of the study "was to test the hypothesis that problem case teaching is more effective than lecture teaching" (8:66). Bocker actually posited three hypotheses:

- H1: Case teaching develops the ability to reproduce knowledge and learned skills better than lecture teaching.
- H2: Case teaching develops the ability to apply knowledge and learned skills to unknown problems better than lecture teaching.
- H3: Case teaching motivates students to learn managerial information more than lecture teaching does. (8:66)

H1 was tested using standard written tests to quantify reproduction of knowledge and learned skills; H2 was tested using written case analyses in exams; and H3 was tested using the thematic apperception test devised by Murray and reformulated by Heckhausen (8:66). Bocker adds that according to Derner, this test is "well accepted in pedagogical research" (8:66). Bocker states that the three hypotheses above are parts of an overall theoretical system that supports the main hypothesis stated earlier. Bocker further assumes that confirmation of the three hypotheses will support the conclusion that "case teaching is more suitable than lecture teaching for teaching business

administration; at a minimum this conclusion should be valid for the courses evaluated" (8:67).

All three hypotheses were tested in a parallel group experiment at the University of Regensburg. A total of four groups of graduate students were enrolled in a course on market planning and control. Two groups were taught using the problem case method and two groups using the lecture method. The course objectives, reading lists, and instructor were identical for all four groups. In addition to the independent variable *teaching method* (controlled), Bocker also observed the effects of the random independent variables of student motivation before the course, bachelor exam scores, and intelligence. The initial student motivation was measured using the thematic apperception test discussed earlier and intelligence was measured by observing four indicators: verbal intelligence, associative intelligence, mathematical intelligence, and visual intelligence; which are part of Amthauer's intelligence structure (8:67).

Bocker includes variable definitions, models tested, and raw averages of the indicators in the article's appendix. His analysis of this data produces four conclusions:

- The teaching mode used has a significant effect on the students' motivation and has some impact on learning. In general, case teaching produces more effective learning than lecture teaching.
- The bachelor exam grade does have a significant correlation with motivation and learning. A good bachelor exam is favorable for learning additional

facts (INCR), but unfavorable for increasing motivation (INCN) (these individuals are highly motivated from the beginning).

- Motivation favors learning to apply knowledge and skills but not learning to reproduce knowledge and skills. (8:68)
- Motivation is not dependent on intelligence (as quantified by Amthauer) in any statistically significant way. (8:68)

Bocker concludes with a discussion of the restrictions of his findings and some suggestions. Bocker states that

> pedagogical research at the university level is difficult since the samples and subsamples are usually small and heterogeneous, and the set of influence factors are not completely known. As a consequence, the findings are statistically not conclusive. The following points are exploratory rather than conclusive. (8:68)

Of the points that followed in the article, the main restriction discussed was that the variable "teacher" was not varied. Therefore, the findings could be a result of teacher-method interaction (i.e. some teachers are better at case teaching or simply like it more) (8:68). Given this restriction and some potential validity problems discussed in the article, Bocker still claims that at a minimum, "problem case teaching stimulates learning more than lecture teaching" for the instructor and subject involved in his study (8:69). He further suggests that case teaching is probably not "superior to lecture teaching for all subjects and goals" (8:69), but some informal experiments show that the case method is effective in "advanced courses devoted to developing the ability to apply techniques and derive solutions for ill-structured problems" (8:69).

Argyris begins his April 1980 article from Academy of Management Review by distinguishing between *single-loop* learning and *double-loop* learning. Argyris defines single-loop learning as learning resulting in the "detection and correction of error without changing the underlying policies, assumptions, and goals" (5:291). "Double-loop learning occurs when the detection and correction of error requires changes in the underlying policies, assumptions, and goals" (5:291). Argyris cites a good example to illustrate the difference between single-loop and double-loop learning.

> A thermostat is a single-loop learner because it detects when the room is too hot or too cold. A thermostat would be a double-loop learner if it questioned why it was set at 65 degrees or why it was measuring heat. (5:291)

Argyris suggests that the case method "may unintentionally reinforce individual and organizational forces against double-loop learning" (5:291). If this claim is accurate then the case method, which is "designed to enhance individual, and through it, organizational double-loop learning, may inhibit both" (5:291). Argyris bases these suggestions on observations and tape recordings made at a three-week executive program which predominately used the case method. The faculty included "stars" of case method teaching from schools such ar Harvard, Virginia, Southern Methodist, Stanford, and Yale (5:291).

Argyris first observes a variety in the degree to which the faculty "conformed to the theory that they espoused"

(5:291). Argyris did find that the faculty agreed on five central features of the case method, which are:

> (1) the use of actual problems of organizations, (2) maximum possible involvement of the participants in stating their views, inquiring into others' views, confronting differences, and making decisions, resulting in (3) a minimal degree of dependence on the faculty members who, in turn (4) hold the position that there are rarely any right or wrong answers, that cases are incomplete and so is reality, and (5) who will strive to make the case method as involving as possible through the creation of appropriate levels of drama." (5:291)

Argyris noted that many instructors used lecturing when it came to teaching basic concepts and procedures. In addition, when it came to ""replaying the bidding," some used role playing" (5:291). Other methods used included simulations, films, and straight long lectures. In fact, when Argyris interviewed instructors, he found that most "believed that all these teaching methods represented the case method" (5:291). Argyris saw this as an inconsistency. He questioned the "truth value of saying in the brochures and during the opening sessions that the case method *differs* from all others when it *includes* all others" (5:292).

Argyris next discusses his observation of the faculty dominating classroom interaction, which seemed to contradict central feature (3) stated earlier. He assumes that a

> rough indication of student dependence is the degree to which faculty members controlled the interactions (1) by asking students questions that they would then answer, (2) by answering specific questions asked by the students, or (3) by presenting statements of the facts about a particular case. (5:292)

Another indication of dependence cited was the "frequency

with which students directed their comments to the faculty members to get their responses to, or evaluation of, their point of view" (5:292). Argyris assumed student independence existed when instructors were not involved in discussion and students carried on discussions with other students (5:292). In his observations Argyris counted, for each seminar session, the number of student-to-student comments or questions and the number of instructor-to-student questions or comments (5:292). The analysis of these counts showed that the "number of student-to-student responses was significantly lower than the number of instructor-to-student responses" (5:292). In fact, the number of instructor-to-student and student-to-instructor responses were "at least twice the number of student-to-student responses" (5:292). The possible consequences of this finding, according to Argyris is that "(1) issues that are important to students may be ignored, (2) students may select or distort information to win, and (3) student dependence on the faculty member may increase" (5:292).

Next Argyris looked at how instructors prepared for case discussions. He found that all the instructors spent several hours reviewing notes "even though they may have taught the case several times" (5:293). Argyris was impressed by two features he found in the instructors' case files. The first was they included "thoughtful action maps for understanding the case" (5:293). Secondly, this information was normally given to the students near the end

of the session (5:293). One faculty member's reason for not giving the information up front was "That would blow the whole game" (5:293). Argyris concludes that by giving this information in a "piecemeal fashion, the faculty member could remain in control of the learning process (especially the involvement and drama)" (5:293). This "control" then can also increase the students' dependence on the faculty (5:294).

Argyris continues with a discussion of how the instructors protected students and themselves and the students protected instructors in the seminar sessions. Whenever instructors "felt that a student was vulnerable, they carefully and covertly controlled the situation to prevent distress" (5:294). "The faculty members appeared to protect the executives from discomfort (and perhaps themselves from low ratings) by hiding their expectations of low performance on the part of the executives" (5:294). If instructors perceived a group as "slow" or "less active than other groups," or "not too well-educated in basic concepts," they would be "careful never to discuss these evaluations with the executives (although they discussed them among themselves and with the officers in charge of executive education)" (5:294). Argyris interviewed executives (students) and found that they were aware of these "protection" issues but never discussed them with instructors. At the same time, the students generally did

not discuss their evaluations of the faculty with the faculty (5:295).

Argyris summarizes the classroom interaction observations by stating that "faculty members (1) dominate the classroom interactions, (2) pace and direct the learning, and (3) take on the responsibility for protecting the students and themselves from losing face" (5:295). In addition, the students "appear to accept the faculty member's role and indeed hold them responsible precisely for these actions" (5:295). Argyris makes the following conclusions from his study, which he calls a "series of games and camouflaging of games" (5:295):

> 1. The theory of learning espoused by the faculty members is significantly different from that implied by their actions. (5:295)
> 2. However, the discrepancy between their theory and their actions is never discussed because the faculty members give clues that it is not discussable. (5:295)
> 3. Executives and faculty members evaluate each other covertly but they do not make the evaluations public and hence subject to test. (5:295)
> 4. The faculty and the students assert that education must be applicable in their work situation, yet they limit the applicability to technical concepts and exclude concepts that are related to executives and organizational learning in the work setting. (5:295)

Argyris concludes with a discussion of the implications of his study. In conjunction with his study of the seminars, Argyris interviewed six directors of executive programs, such as the one studied, and found that their criteria for success of the programs were "(1) teaching new ideas and unfreezing old beliefs, and (2) establishing new friends among executives and faculty members who can serve

as resources to solve problems at some future time" (5:297). Argyris states that even if this seminar program met the first criterion for success, it does not matter because the real problem "was not that executives did not learn new ideas; the problem was that they rarely used them" (5:297). The danger of the second criterion for success is that if making friends becomes too important, "it may create a halo over our programs and unintentionally hide important gaps such as the one of double-loop learning" (5:297). Argyris' final point is that the key to "executive education closing the loop from classroom to organization" is to teach executives "new ideas, to understand how they and their organization may inhibit double-loop learning," and "to design and implement actions to overcome these problems in the back-home situations" (5:298).

Michael A. Berger provides a rebuttal to Argyris in his April 1983 Academy of Management Review article. According to Berger, Argyris' paper

> deserves a reply in order to: (1) underscore the methodological problems in his evaluation; (2) rebut his conclusion that the case method produced the very behavior it was supposed to overcome; and (3) clarify the contradictions associated with education in corporate learning environments. (6:329)

Berger points out that although "there is much wisdom in the Argyris analysis," the context in which he uses the term "case method limitations" avoids

> academic responsibility for: (1) rigorous evaluation; (2) the specification of factors (beyond the case method alone) that also might have affected the learning process; (3) the distinction between

> corporate and graduate education; and (4) the positive features of the case method. (6:329)

Berger claims three methodological flaws "undermine" Argyris' argument. The three flaws are the "preexperimental design, the failure to define the case method, and the lack of impact evaluation" (6:329). Berger cites the preexperimental design as the "most serious weakness in the analysis" (6:329). He states that

> much research in management focuses on one group, studied once in time with the presumption that some agent or treatment caused (or failed to cause) a change, but such studies exhibit so little control that they are of questionable scientific value. (6:329)

In addition, "the numerous threats to internal and external validity inherent in the design and data collection procedures seriously weaken the veracity of Argyris' contentions" (6:329).

Berger sees the "primary focus of Argyris' attack" as "the case method as an educational technique" (6:329). Although "conventional scholarship requires a precise definition and operationalization of a concept to distinguish it from other concepts," Argyris fails to precisely define the case method (6:329). In fact, he discusses the different opinions faculty members had on exactly what the case method is. Without a precise definition of the term, how does one really know what Argyris actually measured (6:330)? "Argyris entered the definitional quagmire but never extricated himself from it" (6:330).

The third methodological flaw claimed by Berger is the lack of impact evaluation. As a result of his findings, Argyris concluded that the "games" played in the seminars "created conditions quite similar to the organizational problems the course was supposed to overcome in the first place" (6:330).

> He [Argyris] observed the sessions, talked with the participants, and concluded that the case method had limitations. This is like criticizing a surgical technique in the middle of an operation. Little effort was made to determine the ultimate impact of the case method (assuming it could be defined) (6:330).

Argyris also discusses the problem of "transfer of training to the back home situation" (6:330). Berger questions whether the case method alone can be blamed for "low transferability of ideas back to the corporate setting" (6:330). According to Berger, an impact evaluation would have determined the factors causing this problem (6:330).

Berger also sees conceptual flaws in the Argyris analysis. Argyris contended that "the case method produced learner problems of conformity, error camouflage, risk minimization, and face-saving" (6:330). Berger cites several factors other than educational technique that may have contributed to the learner problems. First, since Company X in Argyris' study sent its executives to off-site executive development seminars twice a year, "certain *learner characteristics*, such as the involuntary nature of their participation, their management sophistication, and their prolonged absence from day-to-day operations," may

have caused the executives' behavior (6:330). Second, the "*temporary and fluid involvement of faculty*" in the program could have contributed to learner behavior problems. A third factor to consider is the fact that "30 top executives came from the same company" (6:331). This would support the possibility that the group included "corporate rivals who were careful not to jeopardize their back-home interests by divulging sensitive information" (6:331). The last factor presented by Berger stems from the fact that the "*faculty varied in the skill* in which they handled the case method" (6:331). For this reason, problems in the various sessions may have been caused by the way the case method was applied versus the case method itself (6:331). Berger's point in presenting the alternative factors was "to argue that Argyris failed to conceptualize the many structural factors that may have produced the behavior he observed" (6:331).

Next, Berger addresses Argyris' failure to recognize differences between corporate and graduate education. Berger states that there are four differences between graduate and corporate education. These differences include: "learner characteristics, the base of faculty authority, the political consequences of the learning, and the linkage between education and performance" (6:331).

First, learner characteristics differ because "executives are not students in the traditional sense", but "are adult learners with needs and experience that go well beyond the backgrounds of young graduate students. The

difference is critical because it affects the way the educator and the learner will interact in the education process" (6:331).

Second, the base of faculty authority is different for executives because "grades and future recommendations are irrelevant in corporate education" (6:331). Also, sometimes executives have more real-world expertise than their instructors (6:331).

Third, political consequences for graduate education are quite limited. A student's learning does "not directly affect other students in the classroom" (6:331). The students generally "take their education" and "disperse to different settings" (6:331). On the other hand, since corporate learners are often colleagues, "everything that transpires in the learning setting - *everything* - has political implications for future interests and alliances" (6:331).

Finally, "the connection between education and ultimate learner performance in corporations is loose at best and nonexistent at worst" (6:331). Graduate students "can see the light at the end of the tunnel" and they know that "if they jump through the necessary number of hoops", they will graduate and move on to a new job (6:331). On the other hand, "in corporate education, it is difficult to specify the short term and long term effects of executive development," since "success and failure are defined differently by different people (6:331).

Berger's last point of rebuttal is a discussion of four positive features of the case method which he claims Argyris failed to address. The first positive feature is the fact that "the case method focuses on the executive's analysis of a "typical situation" and therefore "capitalizes on his or her opinions, problem solving skills, and real-world expertise -- resources often lacking in graduate students" (6:332). Since the executive students "possess these attributes, learning and generalization from case to real organization are actually facilitated" (6:332). The second positive feature is that the "case method involves a mystery" which is "implicit in the management dilemma" (6:332). Berger agrees with Argyris' contention that the instructors "withhold of information is control of the learning" (6:332). But, Berger contends that "control is justified when: (1) there is a lack of other bases of authority, (2) the journey is freely taken, and (3) unravelling the mystery is itself a goal of the educational experience" (6:332). The third positive feature of the case method is that it "involves a true to life organizational problem", but not a problem of the student's particular organization (6:332). For this reason political factors generally do not inhibit learning. The final positive feature noted is the case method's "ability to accomplish the learning function in an atmosphere of fun and stimulation" (6:332).

Berger concludes that the question of whether or not the case method has limited applicability to executive development is an important question, but he argues that Argyris' "assertion that the case method is limited is a sweeping generalization, based on the analysis of a three-week program" (6:333). Berger further states that "he [Argyris] assumes that the case method can be accountable (by itself) for learner and faculty behavior that probably took years to develop" (6:333).

Conclusion

It is obvious from the preceding discussion that there is disagreement on what the case method is and how effective it is as a teaching method. However, because of its current widespread use and the fact that it has been used for more than fifty years, it seems unlikely that it will be abandoned in the near future. Instead, industry and academia will most likely continue to search for ways to improve the method's effectiveness. Hopefully, the cases generated as a result of this study will contribute to the goal of increased effectiveness. The next chapter describes the methodology that was used to produce these cases.

III. Methodology

A case-writing method, based on the one described by Leenders and Erskine (18:2), was used to collect data and generate the desired case studies. This method involved conducting personal interviews and analyzing written data. The following are the specific steps that were used to conduct the research:

1. Determine Case Needs/Search for Case Leads. In this study, the case needs were defined by the investigative questions stated in the previous section. These questions were used as a guide in searching for case leads. That is, a conscious effort was made to find interviewees who were likely to have had experiences related to the subjects identified in the investigative questions. The search for case leads was limited to organizations within Air Force Systems Command (AFSC) involved in weapon system acquisition programs or research and development programs, and the Air Force Institute of Technology (AFIT). The case leads that ultimately generated completed cases for this study were based on the research advisor's personal contacts within AFIT and AFSC.

2. First Interview. After the case lead search produced a contact, an interview was scheduled. Prior to the interview, a list of questions was written, as appropriate, to guide the discussion. During this first interview, current or past interviewee experiences

pertaining to the case needs were discussed. In addition, any written background information describing the organization and/or particular experiences was requested.

3. Case Plan Preparation. Following the first interview, a particular experience or issue was selected as a case subject. A proposed opening paragraph was then written and presented to the research advisor. The researcher and advisor then jointly determined if the case should be further pursued and whether additional data was still needed to complete the case.

4. Second Interview. During the second interview, the planned case was presented to the interviewee. In addition, the need for case disguise was discussed and any additional needed information was requested. Before conclusion of the interview, a verbal agreement to proceed with case writing was requested.

5. Information Gathering. Following the second interview, any needed information discovered in step 3 and not provided by the interviewee was researched by contacting others in the organization by telephone or interview, or by researching written documentation.

6. Case Writing. This step consisted of several writing iterations as needed. The research advisor edited drafts and provided guidance. A polished version of the case was then submitted to the interviewee to review for technical accuracy. Following the interviewee's review, the

case was forwarded to AFIT/PA (public affairs) for permission to release.

The next chapter is a compilation of the cases produced by applying this case research method.

IV. Cases

The following three cases were written using the case writing methodology described in the preceding chapter. Appendix B documents the completion of the interviewee and AFIT/PA case reviews which were part of Step 6 of the methodology.

Case 1: The Vanguard Strategic Planning Process

Vanguard -- the strategic planning process used by Air Force Systems Command (AFSC) -- had failed. Since its inception in 1978, Vanguard was intended to help major Air Force commanders forecast their need for effective weapon systems 20 years into the future. Nonetheless, the AFSC commander, General Richardson, was forced to discontinue Vanguard because the operational commanders were dissatisfied with the process and most refused to use it. General Richardson pondered his dilemma -- the need for strategic planning still existed, but the full cooperation and participation of the major commanders was essential for any strategic planning process to work.

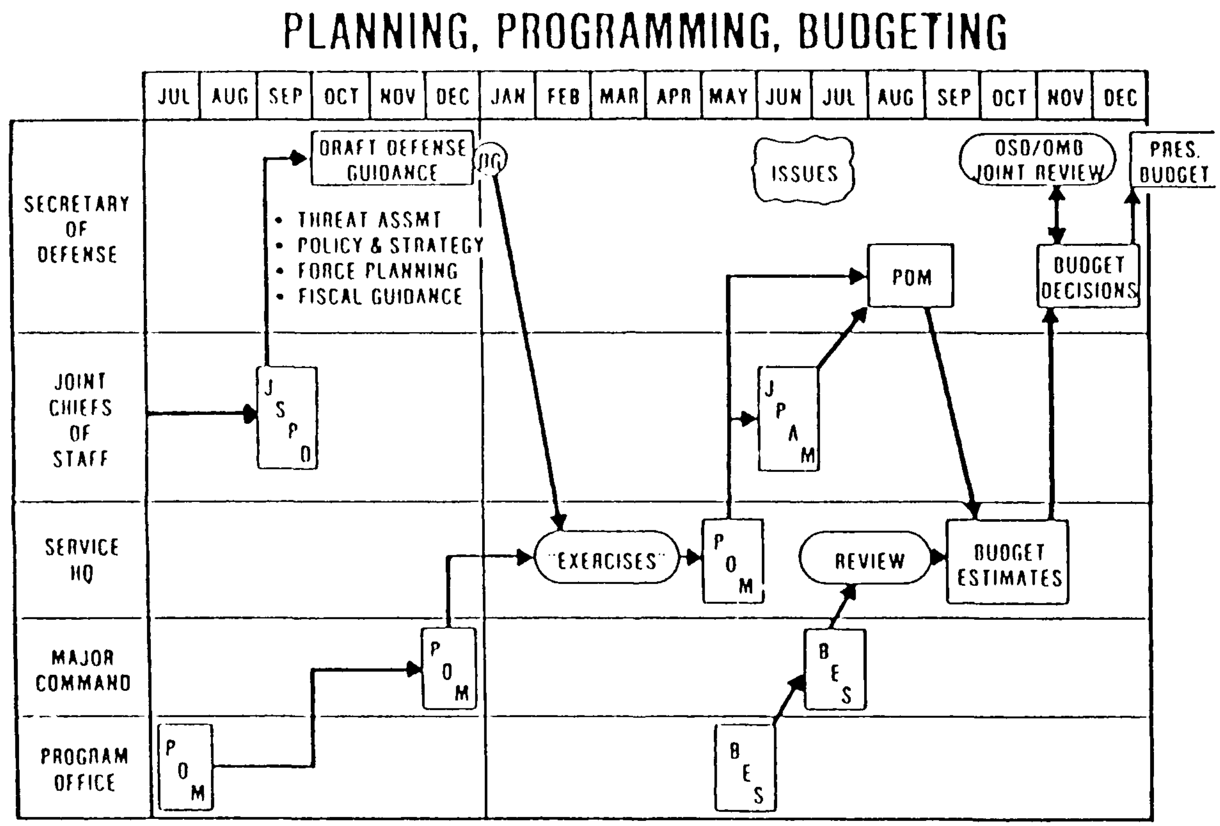
Background. What is strategic planning? It is a process whereby organizations attempt to accurately define long-term objectives, allocate resources, and evaluate the consequences of decisions before they are actually implemented. In the Air Force, strategic planning is especially important due to the long lead time required to develop new technology and produce future weapon systems. Strategic decisions can have an enormous impact on the balance of world power and, in turn, the future of both the United States and the rest of the world (29:5).

Vanguard was a strategic planning process used by AFSC to forecast Air Force weapon system requirements. One important goal of Vanguard was to fit these future requirements into expected future budgets. The desired

result was to improve the Air Force major command's (MAJCOM) inputs to the Planning, Programming, and Budgeting System (PPBS) such that the weapon systems identified as necessary to meet future threats and force structure projections would, in fact, be funded, developed, and delivered to operational units (28).

The PPBS Process. The PPBS is a three-phased planning process used by the Department of Defense (DOD) (see Figure 1). The ultimate aim of the PPBS is to insure that necessary resources are provided to DOD and its components such that national security can be maintained. During the first phase, the *planning* phase, military goals and objectives are set based on national security objectives developed by the National Security Council (NSC), and inputs from the Joint Chiefs of Staff (JCS) and DOD components (e.g. Air Force). These inputs are based on intelligence and threat assessments. The forces and resources needed to achieve the identified military goals and objectives are also outlined during the planning phase. The output of the planning phase is the Defense Guidance (DG) which describes DOD strategy and policy. This document is submitted by the Secretary of Defense (SECDEF) to the DOD components (12:24-25).

In the second phase, the *programming* phase, specific programs are developed by the DOD components to meet the goals and objectives specified in the DG. These programs consist of estimates of the manpower, equipment, and other



JSPD — JOINT STRATEGIC PLANNING DOCUMENT
DG — DEFENSE GUIDANCE
POM — PROGRAM OBJECTIVE MEMORANDUM
JPAM — JOINT PROGRAM ASSESSMENT MEMORANDUM
DES — BUDGET ESTIMATE SUBMISSION
POM — PROGRAM DECISION MEMORANDUM

Figure 1. Planning, Programming, and Budgeting System (PPBS) Process

resources necessary to reach specific objectives. Each program becomes part of the Program Objective Memorandum (POM) which is submitted to the SECDEF for approval. The output of the programming phase is the DOD approved POM (12:32).

The third phase, the *budgeting* phase, generates cost and manpower estimates for the POM programs. However, since budget is a major consideration for SECDEF approval of the POM, the programming and budgeting phases actually overlap and program estimates are generated before final POM approval. For those programs that are actually approved by the SECDEF, program estimates are usually updated prior to their inclusion in the President's Budget at the end of the budgeting phase. The planning and programming phases cover a five-year period (the first five years of the Vanguard planning horizon) called the Five Year Defense Program (FYDP). The budgeting phase concentrates on the first year of the FYDP since the budget for that year will be approved by Congress (12:30-34). Before discussing the Vanguard process, a brief introduction to the Air Force MAJCOMs may be useful.

<u>Air Force Major Commands</u>. The mission of the Air Force is to support national security objectives by gaining and/or maintaining control of the aerospace environment. This includes maintaining forces capable of deterring enemy attacks and, if deterrence fails, fight at the intensity level and duration necessary to attain U.S. military and

security objectives (11:1-2,1-3). The Air Force is organized into various MAJCOMs each of which performs its own role in a total team effort aimed at accomplishing the AF mission. Figure 2 is an organizational chart showing the AF MAJCOMs.

As was stated earlier, Vanguard was created to assist the MAJCOMs in forecasting long-range weapon system requirements. The MAJCOMs that are the largest "owners" of weapon systems are Tactical Air Command (TAC), Strategic Air Command (SAC), Military Airlift Command (MAC), Pacific Air Forces (PACAF), United States Air Forces in Europe (USAFE), Air Training Command (ATC), and Air Force Space Command (AFSPACECOM). Generally, AFSC procures weapon systems for these MAJCOMS. There are several other MAJCOMs, Direct Reporting Units (DRUs), and Separate Operating Agencies (SOAs), but Vanguard focused on the MAJCOMs listed above.

SAC. SAC is responsible for providing and maintaining the Air Force's nuclear capability. SAC controls two legs of the U.S. nuclear triad -- nuclear armed bombers and ground launched nuclear missiles. In addition, SAC supports conventional power projection with its bombers and provides reconnaissance, refueling, and command and control capabilities (25:87).

TAC. TAC organizes, trains, equips, and maintains combat-ready forces capable of rapid deployment and employment. TAC also insures that strategic air defense

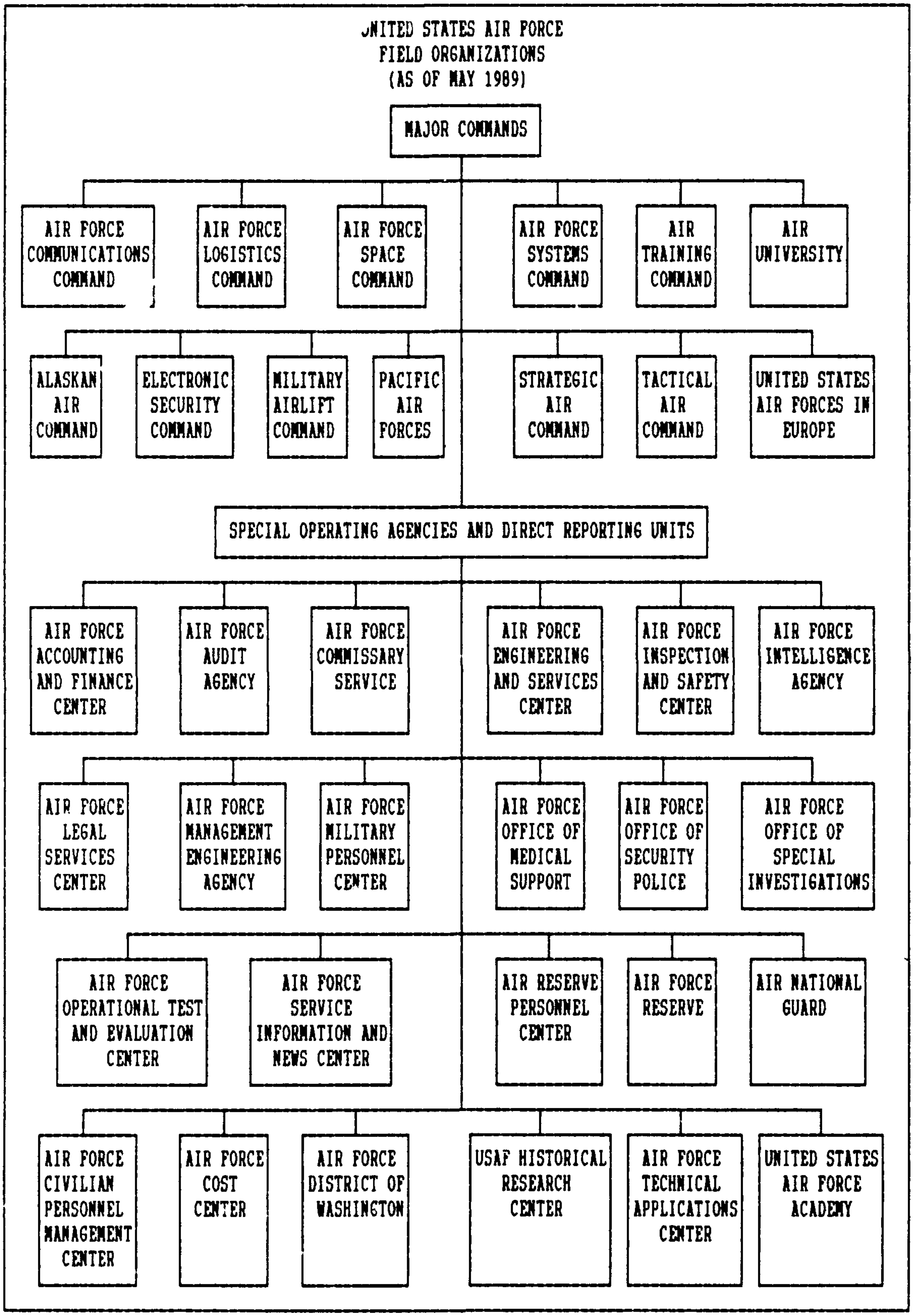


Figure 2. USAF Organizational Chart

forces are prepared to achieve peacetime air sovereignty and wartime air defense (26:90).

MAC. MAC is responsible for the airlift mission which includes deployment, employment, resupply, and redeployment of combat forces and support equipment (19:76).

PACAF. PACAF plans, conducts, and coordinates offensive and defensive air operations in an area extending from the west coast of the Americas to the east coast of Africa and from the Arctic to the Antarctic using support from MAC, TAC and SAC (21:83)

USAFE. USAFE performs a similar function to PACAF except the area covered encompasses all of Europe. USAFE is also a key element of the North Atlantic Treaty Organization (NATO). In fact, the commander of USAFE is also the Commander of Allied Forces in Central Europe (27:97).

ATC. ATC is responsible for basic military training of new recruits, pilot training, aircrew training, and technical training for most non-flying personnel (3:70).

AFSPACECOM. AFSPACECOM is responsible for organizing, training, equipping, and operating forces in support of strategic aerospace defense, space control, and space operations (1:67).

AFSC. AFSC researches, develops, tests, evaluates, and acquires the weapon systems needed by the operational forces to deter and, if necessary, overcome the

threat (2:68). With the Vanguard process, AFSC aimed to perform these duties more effectively.

The Vanguard Process. The Vanguard process dealt with the fifteen years beyond the FYDP (years 6 through 20). The process allowed commanders to consider future threats and force structure projections (beyond five years) and begin forecasting the required resources to meet those projections. The intended result of the process was a more accurate assessment of requirements which would lead to approval and funding of weapons systems that effectively meet threats and national strategic objectives (28).

Vanguard was the responsibility of HQ AFSC/XRP, the Long-Range Planning directorate within HQ AFSC/XR. HQ AFSC/XR was organized into directorates responsible for planning in ten mission areas with overall control of the process located in XRP. These areas were strategic offense; strategic defense; tactical; command, control, and communication (C^3); reconnaissance and intelligence; electronic combat; space systems; special operations forces; mobility; and war reserve material (munitions) (28). The Vanguard process consisted of the following steps:

Step 1. Using various AF and DOD planning documents, AFSC developed initial threat and force structure projections for both current and future forces (28). These planning documents, also used in the PPBS process, are described below.

Defense Guidance (DG). The DG is written by the Office of the Secretary of Defense (OSD) and provides the SECDEF policy, strategy, force planning, resource planning, and fiscal guidance to all DOD organizations (7:18).

Joint Strategic Planning Document (JSPD). The JSPD is a product of the JCS and provides the SECDEF, the NSC, and the President with the JCS's advice on policy, national military strategy, and force recommendations (7:17).

Global Assessment (GA). The GA is an Air Force document which looks ahead 20 years and projects the future operating environment the AF is likely to face (7:14).

Planning Guidance Memorandum (PGM). The PGM is another Air Force document that uses information from the GA to provide HQ USAF and MAJCOM planners with broad executive guidance and long-term perspectives on the AF mission. It establishes long-term (15 years beyond the FYDP) AF priorities within national policy (7:14).

Strategy and Policy Assessment (SPA). The SPA evaluates current U.S. national security objectives, military objectives, and military strategies. It provides a review and critique of the current DG, and prepares planners for participation in the development of the revised DG (7:14).

After performing these initial threat and force structure projections, AFSC, with the help of product division development planning offices (e.g. Aeronautical Systems Division, see Figure 3), compared forecasted future capability requirements from MAJCOM Statements of Operational Need (SONs) to current capabilities and identified future major deficiencies. The major deficiencies identified were then coordinated with the MAJCOMs for validation and acceptance (28). The remaining steps in the Vanguard analysis were performed primarily by HQ AFSC and are described below.

Step 2. At this point, HQ AFSC, again with the help of product division development planning offices, developed alternative systems concepts to counter the major deficiencies. These system concepts were for projected requirements in years 6 through 20. "Current deficiencies" (years one through five) were assumed to have been adequately addressed through the PPBS (FYDP requirements were not considered). That is, changes to requirements already included in the FYDP were not considered. The AFSC/XR directorate (3-letter) responsible for a particular mission area produced cost estimates for any system concepts identified in their area. Some directorates had specific computer models to estimate costs while others used more informal cost estimating methods (28).

The technologies required for development of many of the system concepts identified in years 6 through 20 were

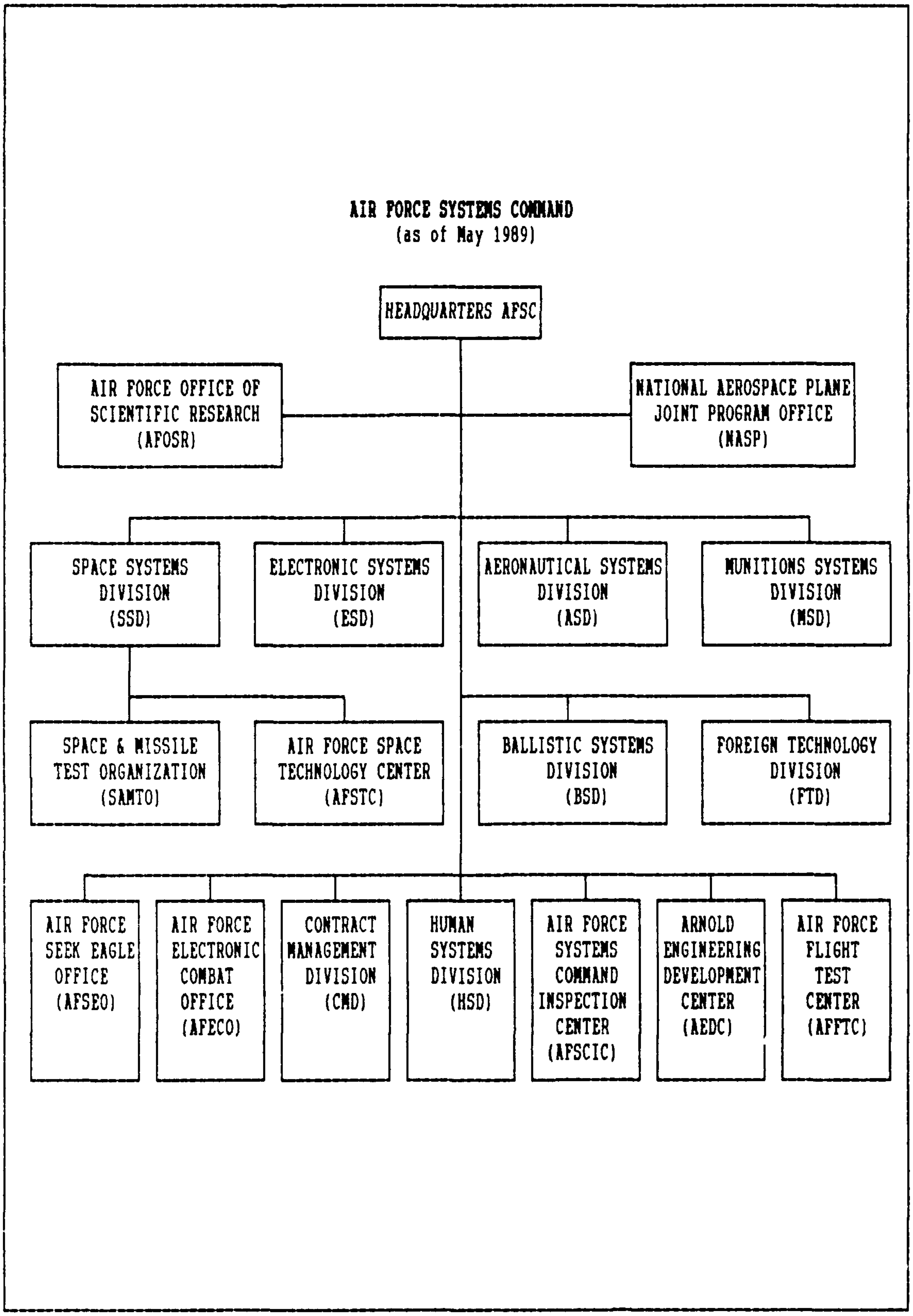


Figure 3. AFSC Organizational Chart

typically not available at the time Vanguard Step 2 was being accomplished. In addition, the XR directorate did not specifically address the feasibility of attaining these technologies because planning for science and technology (S&T) was performed by the Science and Technology Deputy Chief of Staff (DCS) (HQ AFSC/DL). DL activities were typically not associated with the Vanguard process. Also excluded from the Vanguard analysis were any special access ("black") development programs where some of the most promising emerging technologies were being developed and funded (28).

Step 3. The previous step was a "first cut," "unconstrained" iteration, in that system concepts were identified and costed to counter all major deficiencies with no regard for the effect on the magnitude of the budget. Since budget was, and still is, a real-life constraint, the task in step 3 was to try to fit the "essential" system concepts into the program such that the resulting future force structure was realistic. A "realistic" budget was projected for years 6 through 20 by applying a one percent "real growth" rate per year to the budget for the first year of the FYDP and extending this growth rate out to year 20. The resulting "budget line" is shown in Figure 4. The portion of this line from year one to year five was not used because the budget for those years (FYDP) was already programmed. The "one-percent" rule was based on the average annual increase in the AF total obligation authority (TOA)

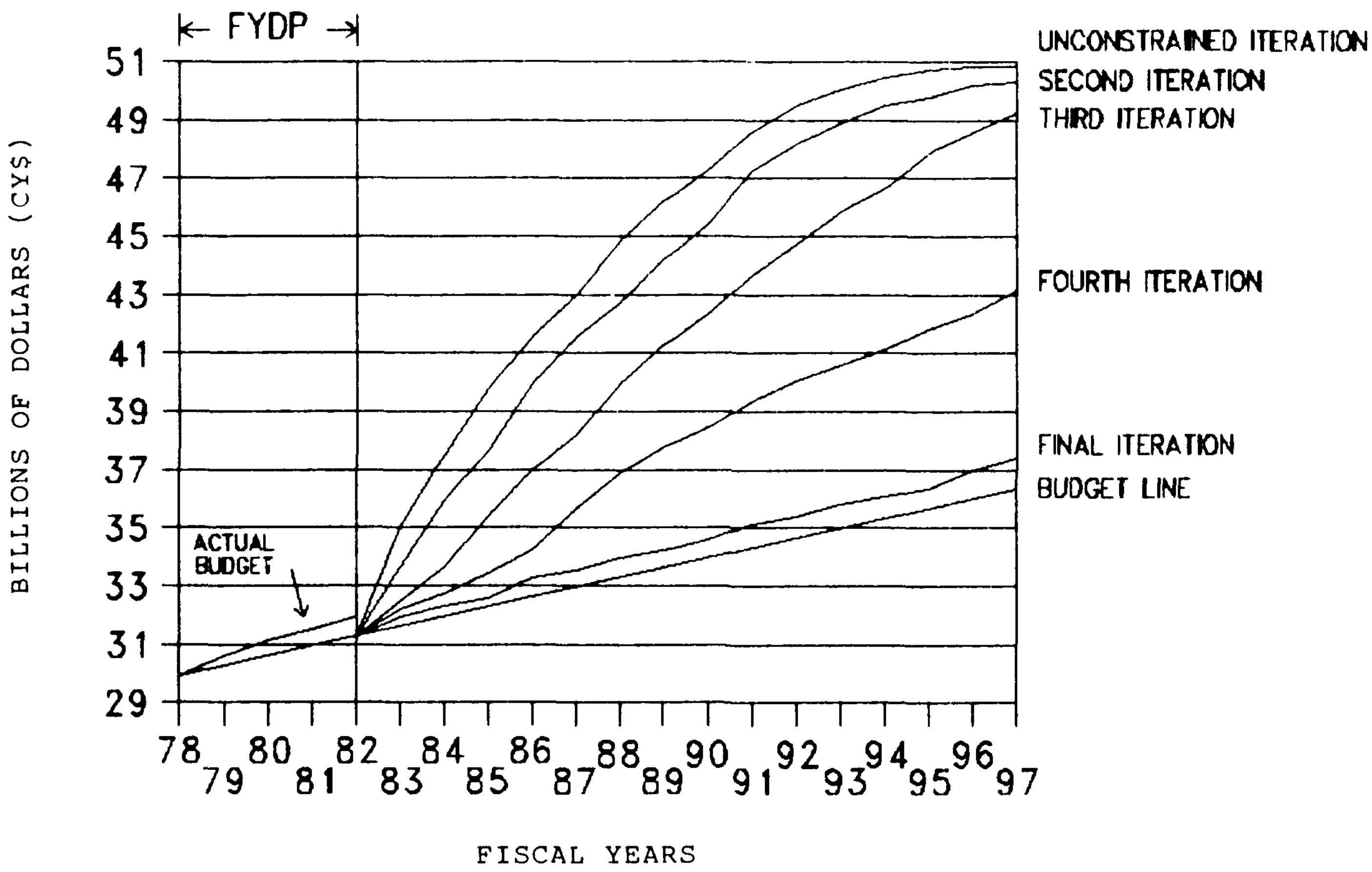


Figure 4. USAF Total Obligation Authority (TOA) (30XX, 3600)

for procurement (30XX) and RDT&E (3600) appropriations over the previous 20-year period (28).

The remainder of this step consisted of an iterative process of adjusting the "unconstrained" program in an attempt to come down to the projected budget. This "adjustment" process was the responsibility of the Program Evaluation Group. This group consisted of all the three-letter directors in HQ AFSC/XR, all of whom were colonels (O-6). There were no official operating instructions or regulations that described how the adjustment process was to be conducted. The Program Evaluation Group would simply meet and through iterative discussions, agree on which system concepts would be eliminated, "slipped," or "stretched out" based on technical, practical, cost, or political considerations. "Slipped" usually meant a time delay in the start of a particular program, not a change in technical capability. "Stretched out" meant developing a technical capability at a slower pace (thus reducing annual funding requirements) and/or reducing technical capability. If after a significant number of iterations the total program had not been brought into line with the forecasted budget, a prorata adjustment was applied across all mission areas to achieve (approximately) the desired budget level (28). Figure 4 graphically illustrates Step 3.

<u>Step 4</u>. After the iterative process in step 3 was complete, HQ AFSC/XR prepared a report on the Vanguard results and also briefed the results to applicable product

divisions and MAJCOMs. These briefings usually took place at the product division or MAJCOM headquarters with the commander and other senior officials attending. At these briefings, the commander and others were often quite vocal in criticizing the analysis presented. The most common disagreements were over the programs that were eliminated in order to meet budget constraints and program cost estimates. In the end, the MAJCOMs generally ignored the Vanguard recommendations when generating POM inputs. In addition, some MAJCOM commanders began delegating responsibility for attending Vanguard annual briefings to subordinates, further indicating their lack of interest in Vanguard (28). These actions by the MAJCOM commanders made the demise of Vanguard inevitable.

Case 2: The Analytic Hierarchy Process (AHP)

Col John Peters, B-1B program director, had a serious problem. The B-1B bomber had failed to perform its mission as advertized -- and Col Peters' job was to "fix it." One of the B-1's main difficulties had been its highly publicized, and often audited defensive avionics problem. At Col Peter's request, the B-1B program team came up with seven options (discussed later) aimed at resolving this issue. Because he expects his decision to be highly scrutinized, Col Peters thinks that some sort of analytical decision tool might be in order. Picking up the phone, he called his friend, Ed Johnson, Director of Engineering for Aeronautical Systems Division (ASD). After hearing Col Peters describe his situation, Ed said, "John, I think we have just what you need. I'm going to put my best man, Capt Jim Hanson, on this right away." It's been three weeks since that phone call and now Capt Hanson has come in with his "fancy" model called the Analytic Hierarchy Process (AHP). Since the AHP is new to Col Peters, he wonders how much credence he should give to the results of the AHP evaluation when making his final decision. He now reflects on the briefing he just sat through that explained the concept of AHP and how it was applied to his problem.

The B-1B Defensive Avionics Problem. The B-1B is a USAF strategic bomber assigned to a dual role nuclear/ theater mission. The aircraft has "three weapons bays providing the flexibility to carry long- and short-range

nuclear air-to-surface missiles, nuclear or conventional gravity bombs, mines, other weapons, or fuel, as required" (31:133). An important B-1B capability is that of low-level penetration of hostile territory. This is accomplished through a radar system that allows the aircraft to follow "the nap of the earth" at near supersonic speeds making enemy radar tracking difficult due to raaar clutter caused by hills, mountains, towers, buildings and trees (31:133).

Highly advanced offensive and defensive electronics equipment were specified for the B-1B.

> The offensive avionics include a modern forward-looking and terrain-following radar, an extremely accurate inertial navigation system, strategic Doppler radar, and radar altimeter. The defensive avionics package is built around the ALQ-161 electronic countermeasures (ECM) system with wide frequency coverage and a tail warning function, supplemented by such expendables as chaff and flares. (31:133)

Development of this defensive avionics system had experienced difficulties. It is this development problem that Col Peters is now confronting.

The development and production of the ECM system was the responsibility of the AIL division of Eaton Corporation. Because of political pressure to field the B-1B quickly, the development and production phases of the system were "overlapped." For this reason, the ECM system was still being developed when aircraft production began. In fact, Col Peters reflected, the system still does not meet user requirements (15). The primary reason for the problem

appears to be a poorly managed program on the part of AIL (Eaton). A March, 1986 review by the Air Force Contract Management Division (AFCMD) faulted Eaton for unsatisfactory product integrity and manufacturing, and marginal quality assurance. The review also found that the "design was so poorly managed that Eaton was averaging up to 800 engineering changes per month" (13:29). The program became so troubled that the B-1B System Program Office (SPO) considered, among other options, terminating the contract with AIL and soliciting a new contract to complete the system's development and production. The seven options considered were:

Option 1. Terminate the AIL contract; take the current AIL-developed system (including hardware, software, and documentation) as it exists at the contract termination date; and replace the ALQ-161 radar warning receiver (RWR) with a modified version of the F-16 RWR. Since the F-16 RWR was designed for a fighter versus a bomber, it could not function to Strategic Air Command (SAC) requirements as is. However, with the funding left over after termination of the AIL contract, some modification could be accomplished that would make the F-16 RWR-based system suitable for use in the B-1B. This system, however, would not necessarily fulfill all SAC requirements (15).

Option 2. Same as option one except instead of integrating the F-16 RWR into the current system, a new contract would be solicited to develop a new RWR. This

option would provide an opportunity to develop an RWR that meets specific SAC requirements. On the other hand, the contracting leadtime required for preparing a Request for Proposal (RFP) and the additional time associated with developing a "new" RWR would further delay the fielding of an acceptable system and could require funding in addition to that left after over after the AIL termination (15).

Option 3. Same as option one except that more time and money would be provided to the organization integrating the F-16 RWR. This additional funding and time would allow more development/modification effort to be accomplished which would increase the chances of meeting or at least approaching SAC requirements (15).

Option 4. Same as option 2 except more time and money would be provided to the new contractor to increase the chances of building a system that meets all SAC requirements (15).

Option 5. Continue with the existing AIL contract to develop the system and attempt to meet all SAC requirements within the funding and time constraints of the existing contract (15).

Option 6. Same as option 5 except more time and money would be provided to AIL to increase the chances of meeting all SAC requirements (15).

Option 7. Rockwell (B-1B prime contractor) would "buy"/take over management of the existing AIL contract. This would decrease the risk associated with the contract

because of Rockwell's management experience and technical knowledge. Rockwell would likely hire key AIL technical personnel, as deemed appropriate, to continue working on the project (15).

To aid in understanding how the AHP was applied to this B-1B problem, a discussion of how the AHP works follows.

AHP. The AHP is a quantitative tool that provides a means for making

> effective decisions on complex issues by simplifying and expediting our natural decision-making processes. Basically, the AHP is a method of breaking down a complex, unstructured situation into its component parts; arranging these parts, or variables, into a hierarchic order; assigning numerical values to subjective judgements on the relative importance of each variable; and synthesizing the judgements to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation. (24:5)

Figure 5 summarizes some advantages of the AHP in making complex decisions.

The three basic principles of the AHP are:

1. Hierarchic representation and decomposition, which we call hierarchic structuring -- that is, breaking down the problem into separate elements.

2. Priority discrimination and synthesis, which we call priority setting -- that is, ranking the elements by relative importance.

3. Logical consistency -- that is, ensuring that elements are grouped logically and ranked consistently according to a logical criterion. (24:26)

These basic principles are discussed in detail below.

Hierarchic Structuring. Saaty provides the following description of hierarchies.

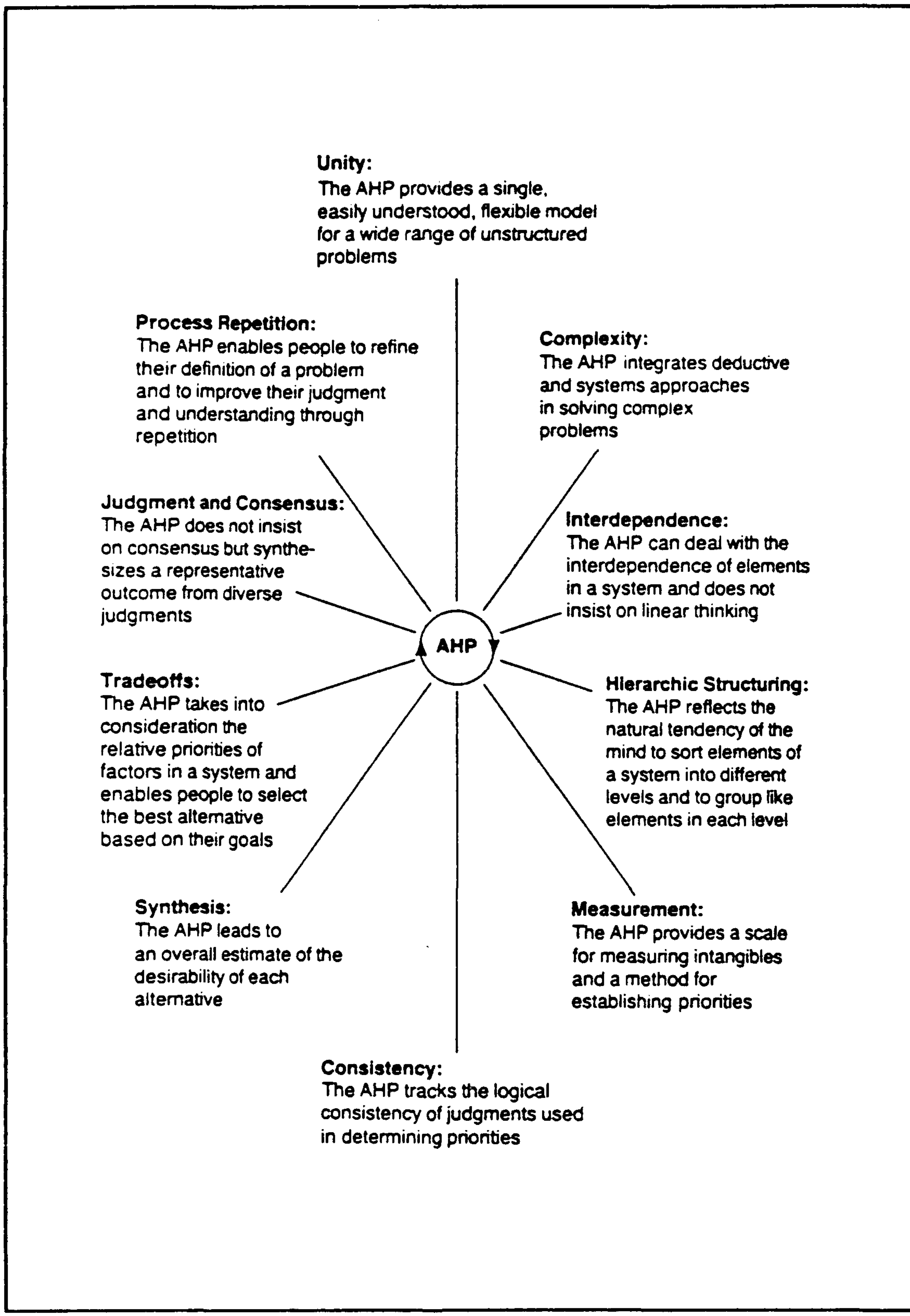


Figure 5. Advantages of the Analytic Hierarchy Process (24:23)

Hierarchies are a fundamental tool of the human mind. They involve identifying the elements of a problem, grouping elements into homogenous sets, and arranging these sets in different levels (24:28).

Saaty also identifies two types of hierarchies: structural and functional. The elements of a structural hierarchy are arranged in "descending order according to structural properties such as size, shape, color or age" (24:28). An example of a structural hierarchy is the chart in Figure 6 that classifies the population of Dayton, Ohio. In contrast

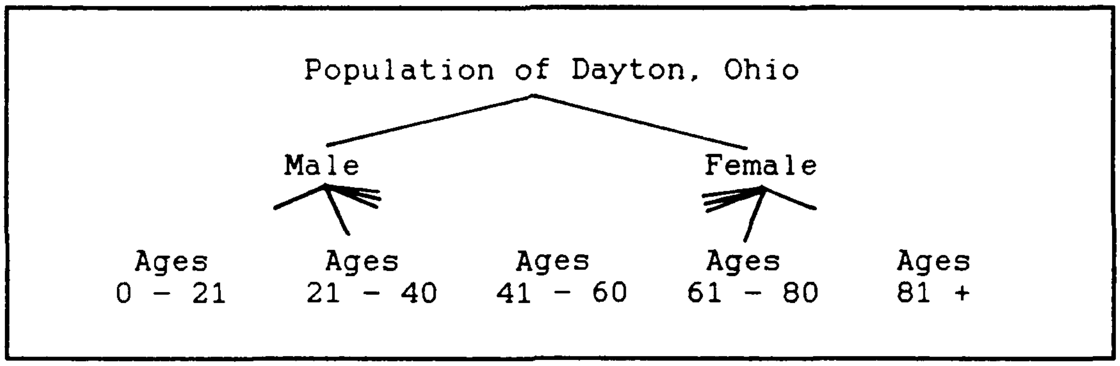


Figure 6. Hierarchy for Classifying the Population of Dayton, Ohio (Structural Hierarchy)

to a structural hierarchy, the elements of a functional hierarchy are arranged according to their essential relationships (24:28). Figure 7 illustrates a functional hierarchy for choosing an automobile. Functional hierarchies, such as the one in Figure 7, "help steer people toward a desired goal," like choosing an automobile (24:28). For this reason, functional hierarchies are used most often when applying the AHP (24:28).

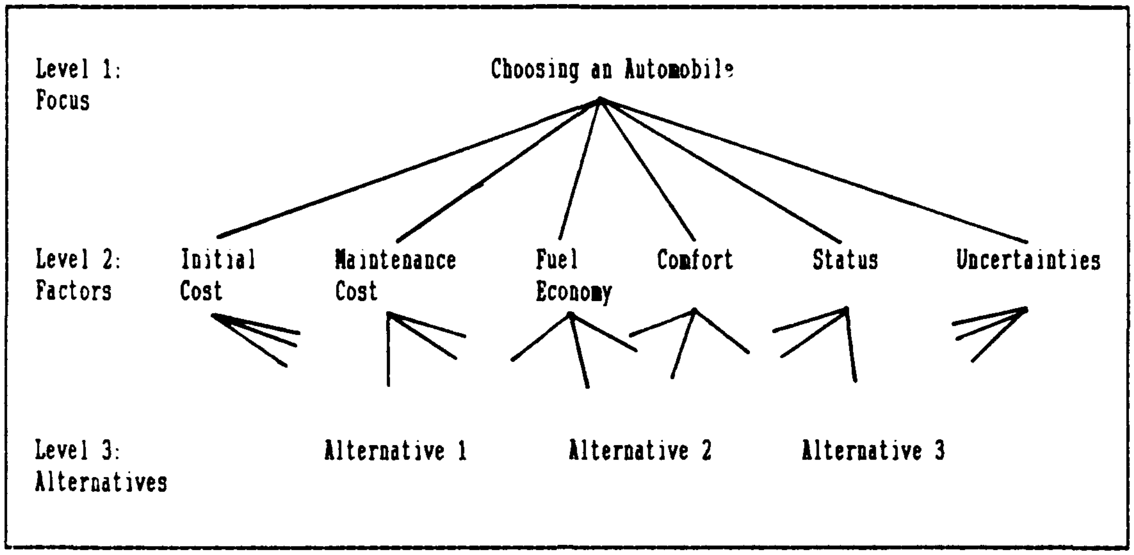


Figure 7. Hierarchy for Choosing an Automobile
[Functional Hierarchy (24:49)

Note in Figure 7 that the element at the top of the hierarchy is the overall objective -- choosing an automobile. This top-level element is referred to as the *focus*. Elements in lower levels of the hierarchy are always compared to each other with respect to a criterion in the immediate higher level (24:28). For this reason, elements in the same level should either "be of the same order of magnitude," or should be placed in different levels (24:28).

There are no strict rules that guide construction of hierarchies. The automobile example in Figure 7 contains three levels but one could use as many levels as deemed necessary to adequately represent the situation. The hierarchy should be flexible enough to accommodate varying levels of complexity (24:29).

"One's approach to constructing a hierarchy depends on the kind of decision to be made" (24:30). When the decision involves choosing between alternatives, as with the automobile example, the bottom level (alternatives) would be a logical starting point. The next level would consist of criteria (or factors) for judging the alternatives. Finally the top level would be the focus or the overall objective (choosing an automobile). The criteria in level 2 would be compared according to how important each is to achieving the focus.

Before continuing, the importance of hierarchy flexibility should again be mentioned. Though a hierarchy for a particular situation may be defined, it should remain flexible so that if another factor is later deemed important, it can easily be incorporated into the model (24:30). A further distinction that should be noted is that of a *complete* versus an *incomplete* hierarchy. The automobile example is a *complete* hierarchy because all elements in one level share every property in the next higher level. An example of an incomplete functional hierarchy is shown in Figure 8. Note that three criteria (educational, cultural, and social) are identified for selecting a best school (focus). However, also note that the criterion "educational" has been broken down into five subcriteria. The other criteria could also be similarly broken down, but the point is that these subcriteria must be compared in relation to the criterion to which they belong

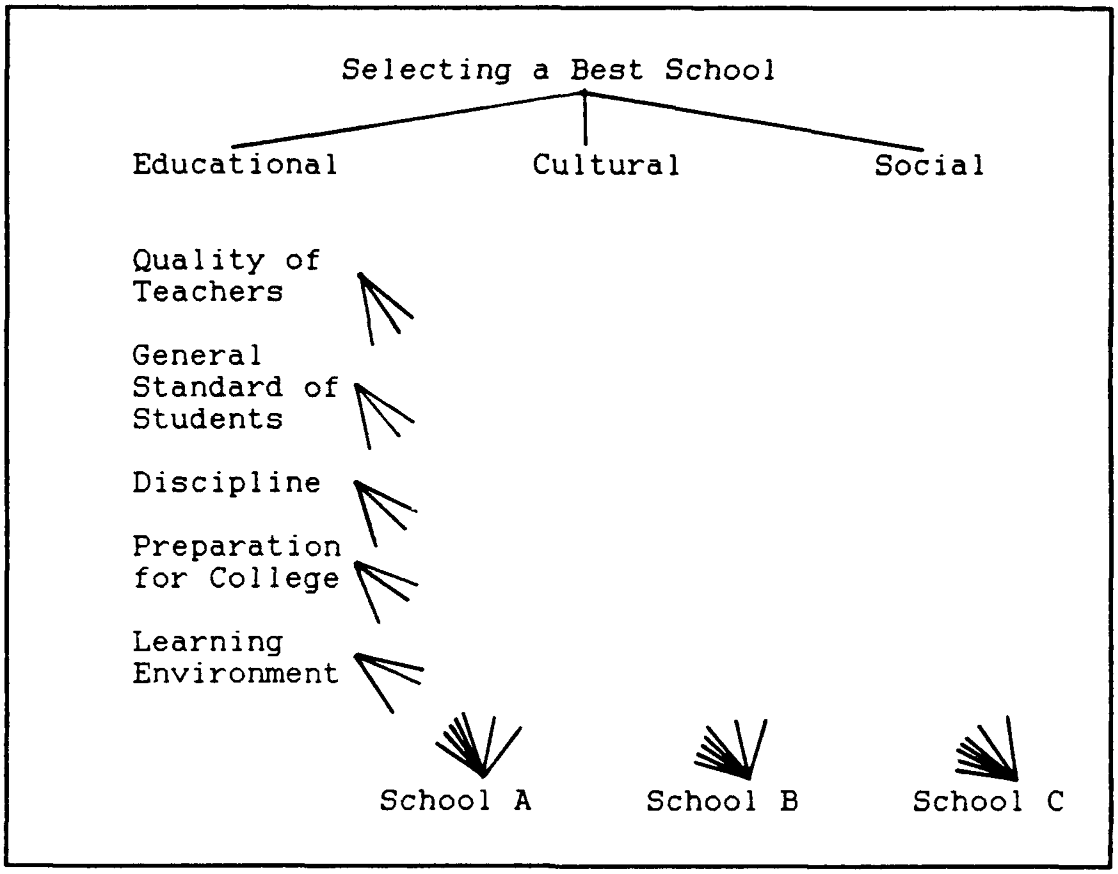


Figure 8. Hierarchy for Selecting a School (24:31)

(educational) but not the others (cultural and social) (24:31).

Priority Discrimination and Synthesis. Once an appropriate hierarchy has been constructed for a particular problem, the next logical step is to look at how the elements of the hierarchy are ranked and how judgements are synthesized into a set of overall priorities. The method used to prioritize and synthesize is mathematical and involves the use of matrices. It is important to note that this mathematical method is probably more efficient than the usual intuitive method of decision making but not

necessarily more accurate. In other words, if a decision maker is uncomfortable with a recommended decision derived by applying the AHP, he or she should not just assume the AHP is correct and continue. It probably means that he or she should repeat the process (24:76). That is, "restructure the hierarchy and improve the judgements" (24:76).

Setting Priorities. "The first step in establishing priorities of elements in a decision problem is to make pairwise comparisons -- that is, to compare the elements in pairs against a given criterion" (24:76). A convenient way to make pairwise comparisons is using a matrix like the one shown in Figure 9. In the figure, the C

C	A_1	A_2	...	A_7
A_1	1			
A_2		1		
.				
.				
.				
A_7				1

Figure 9. Sample Matrix for Pairwise Comparison (24:77)

represents the criterion that would be used to compare the elements in the next lower level. In the automobile example, this would correspond to the *focus* element at the

top level -- choosing an automobile. The "A_1, A_2,... A_7," on the other hand, would be the elements on the next lower level. In the automobile case, these elements would be initial cost, maintenance cost, fuel economy, comfort, status, and uncertainties. We could also move one level down and create new matrix and use "comfort" as the criterion (C) and the A's would now be alternative A, alternative B, and alternative C (24:77).

In determining the elements of the matrix, the convention is to compare a row element to a column element in its row with respect to the criterion C. When comparing elements, one asks: "How much more strongly does this element (or activity) possess -- or contribute to, dominate, influence, satisfy, or benefit -- the property than does the element with which it is compared?" (24:77). To represent these pairwise comparisons, numbers indicating "relative importance of one element over another" are used (24:77). Table 2.1 contains a standard scale for pairwise comparisons.

An illustration of the priority setting procedure, can be seen by referring to the previous example where comfort (automobile) is the criterion (C) and the alternatives (As) are Chevrolet, Thunderbird, and Lincoln. Figure 10 shows this comparison. Note that in Figures 9 and 10, the diagonal elements of the matrix are all one. This is because when comparing a row element with the same element

Table 2.1 The Pairwise Comparison Scale (24:78)

Intensity of Importance	Definition	Explanation
1	Equal importance of both elements	Two elements contribute equally to the property
3	Weak importance of one element over another	Experience and judgement slightly favor one element over another
5	Essential or strong importance of one element over another	Experience and judgement strongly favor one element over another
7	Demonstrated importance of one element over another	An element is strongly favored and its dominance is demonstrated in practice
9	Absolute importance of one element over another	The evidence favoring one element over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between two adjacent judgements	Compromise is needed between two judgements
Reciprocals	If activity i has one of the preceding numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	

Comfort	C	T	L
Chevrolet (C)	1	1/2	1/4
Thunderbird (T)	2	1	1/2
Lincoln (L)	4	2	1

Figure 10. Simple Matrix for Comparing Three Cars for Comfort (24:79)

in a column their relative importance is logically equal to one.

The procedure for getting the remaining six elements of the matrix can be described in four steps. First, the Thunderbird (row) is compared to the Chevrolet (column) and decide that the Thunderbird is determined to be twice as comfortable as the Chevrolet. Thus the corresponding matrix element is two. Second, the Lincoln (row) is compared to the Chevrolet (column) and it's decided that the Lincoln is four times as comfortable as the Chevrolet which gives a matrix element of four. Third, the Lincoln (row) is compared to the Thunderbird (column) and is considered twice as comfortable as the Thunderbird giving a matrix element of two. Finally, the other three elements of the matrix are the reciprocals of the elements just determined because they are simply reverse comparisons. The pairwise comparison matrix is now complete (24:78-80).

Synthesis. Now that the pairwise comparisons have been made, the resulting judgements can now be synthesized to estimate the relative priorities of the three cars with respect to the criterion "comfort." First, the values in each column are summed (see Figure 11). Next, each element in each column is divided by the column total. This generates the *normalized matrix* shown in Figure 12. The final step is to take the average of the values in each row of the normalized matrix as shown in Figure 13 below. The resultant values represent the overall relative

Comfort	C	T	L
C	1	1/2	1/4
T	2	1	1/2
L	4	2	1
Column Total	7	3.5	1.75

Figure 11. Synthesizing the Judgements (24:80)

Comfort	C	T	L
C	1/7	1/7	1/7
T	2/7	2/7	2/7
L	4/7	4/7	4/7

Figure 12. Normalized Matrix (24:81)

$$(1/7 + 1/7 + 1/7)/\ 3 = 1/7 = 0.14$$

$$(2/7 + 2/7 + 2/7)/\ 3 = 2/7 = 0.29$$

$$(4/7 + 4/7 + 4/7)/\ 3 = 4/7 = 0.57$$

Figure 13. Overall Relative Priorities

priorities (preferences) for the Chevrolet (0.14), Thunderbird (0.29), and the Lincoln (0.57) with respect to

the criterion "comfort". This set of priorities is also called the *priority vector* (24:80).

Consistency. The results of the synthesis of the automobile example were very simple because all of the normalized matrix columns were identical. This indicates that the pairwise comparison matrix (Figure 10) was judgementally consistent. The matrix is consistent because the relationship between the Chevrolet and the Thunderbird in the first row

$$C = (1/2)T$$

and the relationship between the Chevrolet and the Lincoln in the first row

$$C = (1/4)L$$

means that

$$(1/2)T = (1/4)L$$

and thus

$$T = (1/2)L$$

which is the value of the second row, third column element (24:81-82). If there was inconsistency in the matrix, this relationship between elements would not exist.

Although consistency is desirable, it is not always easy to achieve, especially when we are dealing with more complex hierarchies. These larger hierarchies produce larger comparison matrices, which means that there are more comparative judgements to make. In addition, in real-life situations specific circumstances can not only influence judgements but can also change judgements. Thus,

realistically we can only aim to minimize inconsistency in our judgements. The AHP uses the *consistency ratio* to measure the overall consistency of judgements. The standard convention is that a *consistency ratio* of 0.10 or less is acceptable. A ratio higher than 0.10 indicates random judgements (24:82-83).

To illustrate the calculation of a consistency ratio, the original pairwise matrix (Figure 10) for the automobile example, which was consistent, will be made inconsistent by changing the second row, third column element from 1/2 to 1/4, and thus changing the third row, second column element from 2 to 4 (see Figure 14). Figure 15 shows the results of

Comfort	C	T	L
C	1	1/2	1/4
T	2	1	1/4
L	4	4	1
Column Total	7	5.5	1.5

Figure 14. Inconsistent Matrix (24:83)

applying the synthesis procedure (described earlier) to this matrix. Note that the change in judgements changed the changed the priority vector. An indication of the significance of this change can be determined by calculating the inconsistency of the new matrix. This is done by

Comfort	C	T	L	Row Sums	Average Row Sum
C	1/7	1/11	1/6	0.40	0.40/3 = 0.13
T	2/7	2/11	1/6	0.63	0.63/3 = 0.21
L	4/7	8/11	4/6	1.97	1.97/3 = 0.66

Figure 15. Normalized Matrix, Row Sums, and Overall Priorities (24:83)

comparing the inconsistency of the current judgements with that obtained when judgements are random (24:84).

The mathematical equation for the consistency ratio (CR) is

$$CR = CI/RI \qquad (1)$$

where CI is the consistency index and RI is the random consistency indicator. The equation for the consistency index (CI) is

$$CI = (B_{max} - n)/\ (n - 1) \qquad (2)$$

where B_{max} is calculated below and n is the dimension of matrix. Values of RI have been calculated for different sized matrices and can be found in Saaty's book (24:84). The value of RI for a matrix with a dimension of 3 is 0.58 (24:84). B_{max} must now be calculated so that CR can be determined. The first step in calculating B_{max} is to multiply the first column of the inconsistent matrix by the relative priority of the Chevrolet (0.13), the second column by the relative priority of the Thunderbird (0.21), and the

third column by the relative priority of the Lincoln (0.66). Next the row of elements of the scaled matrix are totaled (see Figure 16). Next, each element of this column of row totals must be divided by the corresponding element from the priority vector (see Figure 17). These resulting three

Comfort	C(0.13)	T(0.21)	L(0.66)
C	1	0.5	0.25
T	2	1	0.25
L	4	4	1

Comfort	C	T	L	Row Total
C	0.13	0.11	0.17	0.41
T	0.26	0.21	0.17	0.64
L	0.52	0.84	0.66	2.02

Figure 16. Totaling the Entries (24:84)

$$\begin{bmatrix} 0.41 \\ 0.64 \\ 2.02 \end{bmatrix} \div \begin{bmatrix} 0.13 \\ 0.21 \\ 0.66 \end{bmatrix} = \begin{bmatrix} 3.15 \\ 3.05 \\ 3.06 \end{bmatrix}$$

Figure 17. Determining B_{max} (24:85)

values can now be averaged to obtain B_{max}.

$$B_{max} = (3.15 + 3.05 + 3.06)/ 3 = 3.09$$

Substituting the values for B_{max} and n into the equation (1) gives

$$CI = (3.09)/ (3 - 1) = 0.045$$

Now, substituting the values of CI and RI into the equation (2) yields

$$CR = 0.045/ 0.58 = 0.08$$

This value of CR indicates an acceptable level of inconsistency since it is less than 0.10 (24:84). If the consistency ratio had been above 0.10, improved consistency would likely be desired. One method for improving the consistency is to rank the alternatives in descending order according to the priorities generated in the first synthesis. A new pairwise comparison matrix can then be developed by referring to this ranking (24:85). A more convenient method would be to use a computer program that automatically determines which elements of the matrix contribute most to the inconsistency. One such computer program will be discussed later.

Calculating Overall Priorities. The ultimate goal of the AHP, as it applies to the automobile example, is to calculate the overall priorities for each option based on the entire hierarchy. This means that a pairwise comparison matrix, like the one in Figure 10, would have to be constructed for each of the other level 2 factors. Such a matrix comparing the six level 2 factors with respect to the *focus* (choosing an automobile) would also have to be constructed. Then, synthesis calculations, like those done for the example matrix (for the factor "comfort"), would be necessary for each of these seven matrices. Figure 18 shows the seven matrices along with their corresponding priority vectors.

Thus far, priority vectors relating the level two factors to the *focus* and the three options (level 3) to each

CHOOSE AUTO	INITIAL COST (IC)	MAINT COST (MC)	FUEL ECON (FE)	COMFORT (C)	STATUS (S)	UNCERT (U)	PRIORITY VECTOR
IC	1	2	4	4	8	8	0.44
MC	0.5	1	2	2	4	4	0.22
FE	0.25	0.5	1	1	2	2	0.11
C	0.25	0.5	1	1	2	2	0.11
S	0.125	0.25	0.5	0.5	1	1	0.06
U	0.125	0.25	0.5	0.5	1	1	0.06

INITIAL COST	C	T	L	PRIORITY VECTOR
C	1	2	4	0.57
T	0.5	1	2	0.29
L	0.25	0.5	1	0.14

MAINT COST	C	T	L	PRIORITY VECTOR
C	1	2	2	0.50
T	0.5	1	1	0.25
L	0.5	1	1	0.25

FUEL ECON	C	T	L	PRIORITY VECTOR
C	1	2	4	0.57
T	0.5	1	2	0.29
L	0.25	0.5	1	0.14

COMFORT	C	T	L	PRIORITY VECTOR
C	1	0.5	0.25	0.14
T	2	1	0.5	0.29
L	4	2	1	0.57

STATUS	C	T	L	PRIORITY VECTOR
C	1	0.33	0.17	0.10
T	3	1	0.5	0.30
L	6	2	1	0.60

UNCERTAIN	C	T	L	PRIORITY VECTOR
C	1	1	0.5	0.25
T	1	1	0.5	0.25
L	2	2	1	0.50

Figure 18. Pairwise Comparison Matrices with Priority Vectors

of the level 2 factors have been generated. These priority vectors can now be used to compute a vector of overall priorities for the entire hierarchy. Figure 19 shows how this vector is computed. Each of the three elements in the six, level 2 priority vectors are first multiplied by the priority (or weight) of the corresponding factor (e.g., comfort). Now, all of the "weighted" first elements are summed to get the overall priority of option A (Chevrolet). This same summing operation is repeated for the second and third elements to give the overall priorities of option B (Thunderbird) and option C (Lincoln), respectively (24:86). As can be seen in Figure 19, the Chevrolet's priority (0.46) is significantly higher than that of the Thunderbird or Lincoln. This means that based on the AHP, the Chevrolet should be chosen.

Overall Consistency. In the simplified automobile example, all of the matrices were consistent. That is, the CR values for all matrices was zero (0). However, as stated earlier, more complicated, real-life examples would likely contain as least some inconsistent matrices. To calculate the overall consistency of the hierarchy, the consistency index (CI) of each of the six level 2 matrices would first be multiplied by the corresponding factor priority and then summed to obtain an "overall" CI. Then the same operation would be applied to matrices to obtain an "overall" RI. The ratio of the "overall" CI to the "overall" RI would then

	INITIAL COST (0.44)		MAINT COST (0.22)		FUEL ECONOMY (0.11)		COMFORT (0.11)		STATUS (0.06)		UNCERT (0.06)		VECTOR OF OVERALL PRIORITIES
CHEVROLET	0.57 x 0.44	+	0.50 x 0.22	+	0.57 x 0.11	+	0.14 x 0.11	+	0.10 x 0.06	+	0.25 x 0.06	=	0.46
T-BIRD	0.29 x 0.44	+	0.25 x 0.22	+	0.29 x 0.11	+	0.29 x 0.11	+	0.30 x 0.06	+	0.25 x 0.06	=	0.28
LINCOLN	0.14 x 0.44	+	0.25 x 0.22	+	0.14 x 0.11	+	0.57 x 0.11	+	0.60 x 0.06	+	0.50 x 0.06	=	0.26

Figure 19. Calculation of Vector of Overall Priorities

give the "overall" CR for the hierarchy. Figure 20 illustrates this procedure.

$$CI_{ov} = CI_{ic}\ (0.44) + CI_{mc}\ (0.22) + CI_{fe}\ (0.11) + CI_{c}\ (0.11) + CI_{s}\ (0.06) + CI_{u}\ (0.06)$$

$$RI_{ov} = RI_{ic}\ (0.44) + RI_{mc}\ (0.22) + RI_{fe}\ (0.11) + RI_{c}\ (0.11) + RI_{s}\ (0.06) + RI_{u}\ (0.06)$$

$$CR_{ov} = CI_{ov} \ / \ RI_{ov}$$

Where: ov = overall; ic = initial cost; mc = maintenance cost; fe = fuel economy; c = comfort; s = status; u = uncertainties

Figure 20. Calculation of Overall Consistency Ratio

<u>AHP Computer Programs</u>. All of the calculations performed above become quite tedious as the hierarchy gets larger. Fortunately, a computer software package, <u>Expert Choice</u> has been developed for applying the AHP. <u>Expert Choice</u> will guide the user through a menu system. The user can build the hierarchy and fill in the appropriate pairwise comparison matrices. The program does all the remaining calculations including the computation of priority vectors and consistency ratios. In addition, if the user is not satisfied with any matrix CR, the program will indicate which judgements contribute most to the inconsistency. This allows the decision maker to review these judgements and

make any changes deemed necessary. Expert Choice was used to apply the AHP to the B-1B problem.

Applying the AHP to the B-1B Defensive Avionics Problem. The seven options the B-1B SPO considered (discussed earlier) were placed at the bottom level of a hierarchy constructed by Capt Hanson to model this problem (see Figure 21). At the second level were five different

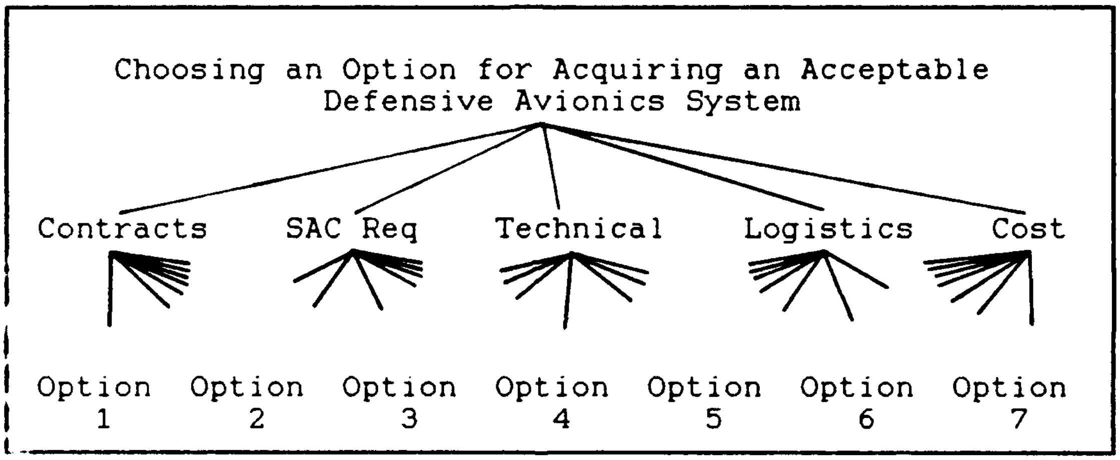


Figure 21. Hierarchy for Choosing a B-1B Defensive Avionics Option (14:6)

Air Force evaluation panels that evaluated each option and set priorities. The *focus* (top level) was "choosing an option for acquiring an acceptable defensive avionics system." Capt Hanson began his analysis by meeting with Col Peters; Lt Col Watson, the director of B-1Q (office responsible for the defensive avionics system); and Lt Col Baker, who was Lt Col Watson's deputy. Capt Hanson first explained how the AHP process worked and then asked each of the men to complete a comparison matrix by judging the

relative importance of the five panels (level 2) with respect to the *goal* using the AHP rating scale (Figure 5). That is, they each made comparative judgements on which advisory panels were most important when selecting the option that would best provide an acceptable defensive avionics system for the B-1B. Once each of the men completed his matrix, Capt Hanson combined the three sets of judgements into a combined matrix by taking corresponding elements from each individual matrix and computing the geometric mean (15).

The geometric mean was used instead of the arithmetic mean because the geometric mean is generally more appropriate when dealing with ratios (10:179). For example, consider two different panel members comparing option 1 (row) to option 2 (column). If the first person thinks that option 1 is twice as preferable as option 2, he or she would enter a 2 in the row one, column two element of the comparison matrix. On the other hand, the second person may think just the opposite and would therefore enter 0.5 into that same matrix element. Now, assuming each person is judgementally consistent, each would enter the reciprocal of the first judgement value in the row two, column one element of the matrix. Figure 22 shows the comparison matrices just referred to and the result of "combining" the two judgements using the arithmetic mean and the geometric mean method. Note that the arithmetic mean method gives the same value for the "reciprocal" elements! This is not

Person 1

SAC	Option 1	2	...	7
1	1	2		
2	0.5	1	...	
.		.		
.		.		

Person 2

SAC	Option 1	2	...	7
1	1	0.5		
2	2	1	...	
.		.		
.		.		

Calculations

Arithmetic Mean: $(2 + 0.5)/2 = 1.25$

Geometric Mean: $(2 \times 0.5)^{0.5} = 1$

Combined Matrices

Arithmetic

SAC	Option 1	2	...	7
1	1	1.25		
2	1.25	1	...	
.		.		
.		.		

Geometric

SAC	Option 1	2	...	7
1	1	1		
2	1	1	...	
.		.		
.		.		

Figure 22. Arithmetic Mean vs. Geometric Mean

consistent. By definition, the values of these elements should be reciprocals of each other. Note that using the geometric mean method gives combined element values that are reciprocal and therefore consistent. The reason for the difference between the two methods is that the arithmetic

mean does not give each ratio value being "averaged" equal weight. The geometric mean method does give equal weight to the ratio values and is therefore appropriate to use in this case (10:179-180).

After receiving permission from Col Peters to proceed, Capt Hanson next met individually with each panel member (all five panels) to perform his or her evaluation. Each of the five panels consisted of a varying number of individuals ranging from two to five. Capt Hanson met with the individuals and explained how the AHP worked and then asked them to compare the seven options using a seven-by-seven pairwise comparison matrix (corresponding to the seven options). Capt Hanson explained that the options should be compared using the AHP scale and should be judged from the point of view of the individual's specialty area. Of course, he reminded them that the judgements should be based on "which option will best provide an acceptable defensive avionics system." He also noted that not all options (perhaps none) would produce a system that met <u>all</u> SAC requirements. However, all options should provide an acceptable system. Each individual matrix within a panel was "combined" into the panel comparison matrix by using the geometric mean method (15).

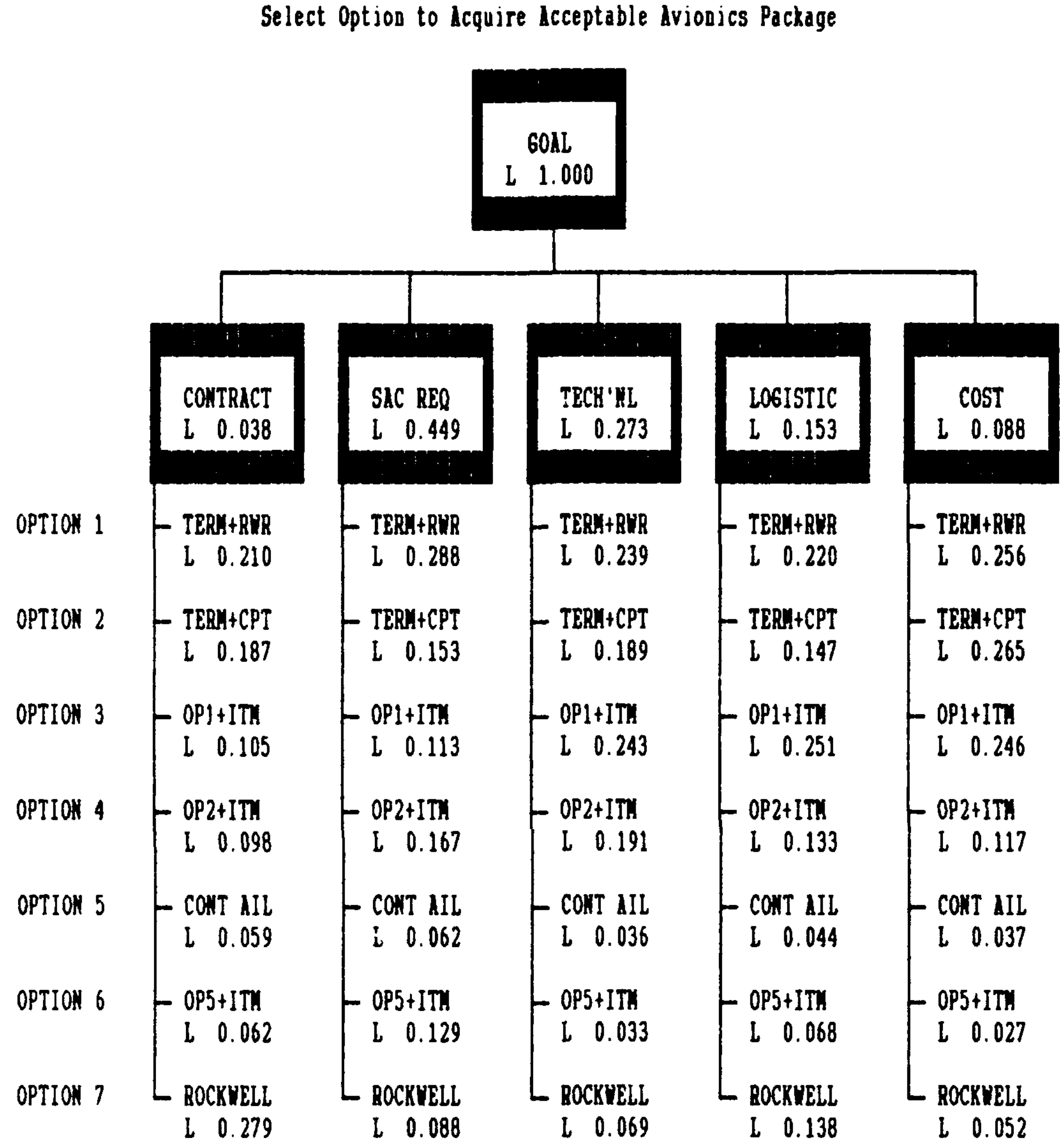
In several of the panels, comparisons had to be repeated because of inconsistency problems. For instance, Capt Hanson noted that within the contracts panel, there seemed to be a noticeable difference in judgements between

civilian and military panel members. A meeting of all panel members was called to determine the reason for the lack of consensus. It turned out that not all members of the panel were aware of some information concerning the background of the problem and basic goals and requirements associated with the defensive avionics system. After all members were "brought up to speed," the individual evaluations were repeated and were significantly less variable (i.e., more consistent) (15).

Capt Hanson noted a problem with the SAC panel evaluations that was a bit different. Initially, there were two evaluators and their individual comparison matrices had fairly high inconsistency ratios. These inconsistencies seemed to be caused by the evaluators giving all the options about the same priority. After discussing this with SAC panel members, Capt Hanson discovered there was a general reluctance among the group to make judgements about the options for fear of reprimand by SAC superiors. In other words, the panel members felt that their superiors would think that these types of judgements should be reserved for HQ SAC. After Capt Hanson discussed this with the two panel members, the individual evaluations were repeated with some reduction in inconsistency noted. At this point, one of the two SAC personnel had to return to headquarters leaving only one SAC evaluator to continue with the B-1B evaluation. This individual repeated the evaluation for a third time with considerably more understanding of how the AHP works.

This third evaluation was significantly more consistent. Because the second SAC evaluator was no longer available, this single evaluation had to be used as the overall SAC comparison matrix (15).

After combining all the individual comparison matrices using the geometric mean method, Capt Hanson entered the combined panel judgements into the EXPERT CHOICE model to synthesize a final judgement (15). Figures 23 through 30 show output from the EXPERT CHOICE program. Figure 23 shows the entire hierarchy with calculated priorities and a description of each of the seven options. Figure 24 shows the combined comparison matrix judging the relative importance of each panel with respect to the *goal*. It also shows calculated relative priorities and the matrix inconsistency ratio. Figures 25 through 29 show this same information for each of the five lower level matrices which judge the relative preference for the seven options with respect to the appropriate panel. Finally, Figure 30 shows the synthesis of the entire hierarchy giving the overall inconsistency and the relative priorities of each option. According to this AHP evaluation, option one of the seven previously discussed options was preferred. Remember that option one called for terminating the AIL contract and replacing the ALQ-161 RWR with a modified version of the F-16 RWR. These were the results that were briefed to Col Peters (15).



GOAL -- Select option to acquire acceptable avionics package.
CONT AIL -- CONTINUE WITH REMAINDER OF AIL CONTRACT
CONTRACT -- CONTRACTS PANEL
COST -- COST PANEL
LOGISTIC -- LOGISTICS PANEL (WR-ALC)
OP1+ITM -- TERMINATE AIL + F-16 RWR + INCREASE TIME AND MONEY
OP2+ITM -- TERMINATE AIL + COMPETITION FOR NEW RWR + INCREASE TIME AND MONEY
OP5+ITM -- CONTINUE WITH AIL CONTRACT BUT INCREASE TIME AND MONEY
ROCKWELL -- CONTINUE WITH AIL CONTRACT BUT MANAGED/BOUGHT BY ROCKWELL
SAC REQ -- SAC REQUIREMENTS PANEL
TECH'NL -- TECHNICAL PANEL
TERM+CPT -- TERMINATE AIL + COMPETITION FOR NEW RWR
TERM+RWR -- TERMINATE AIL + F-16 RWR
L -- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT

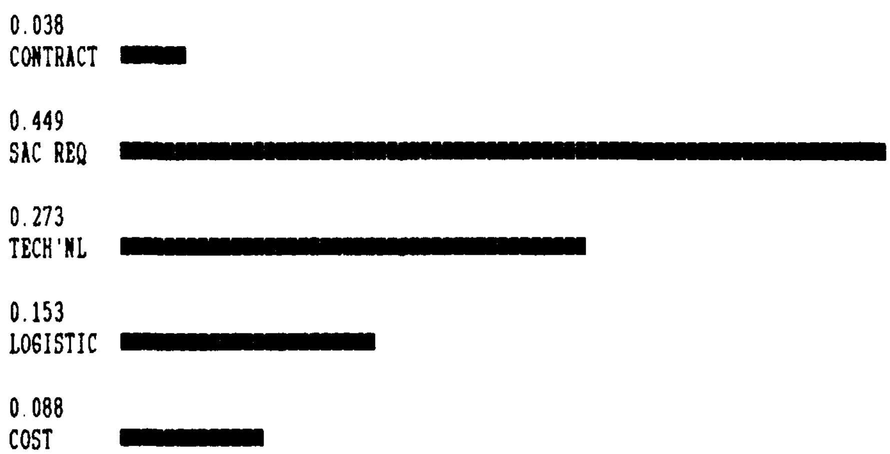
Figure 23. B-1B Defensive Avionics Hierarchy

JUDGEMENTS AND PRIORITIES WITH RESPECT TO
GOAL TO Select Option to Acquire Acceptable Avionics Package.

	CONTRACT	SAC REQ	TECH'NL	LOGISTIC	COST
CONTRACT		(7.0)	(5.9)	(5.9)	(3.8)
SAC REQ			2.3	3.4	5.5
TECH'NL				2.6	3.8
LOGISTIC					2.1
COST					

Matrix entry indicates that ROW element is ...
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element
unless enclosed in parenthesis.

CONTRACT : CONTRACTS PANEL
SAC REQ : SAC REQUIREMENTS PANEL
TECH'NL : TECHNICAL PANEL
LOGISITC : LOGISTICS PANEL (WR-ALC)
COST : COST PANEL



INCONSISTENCY RATIO = 0.048

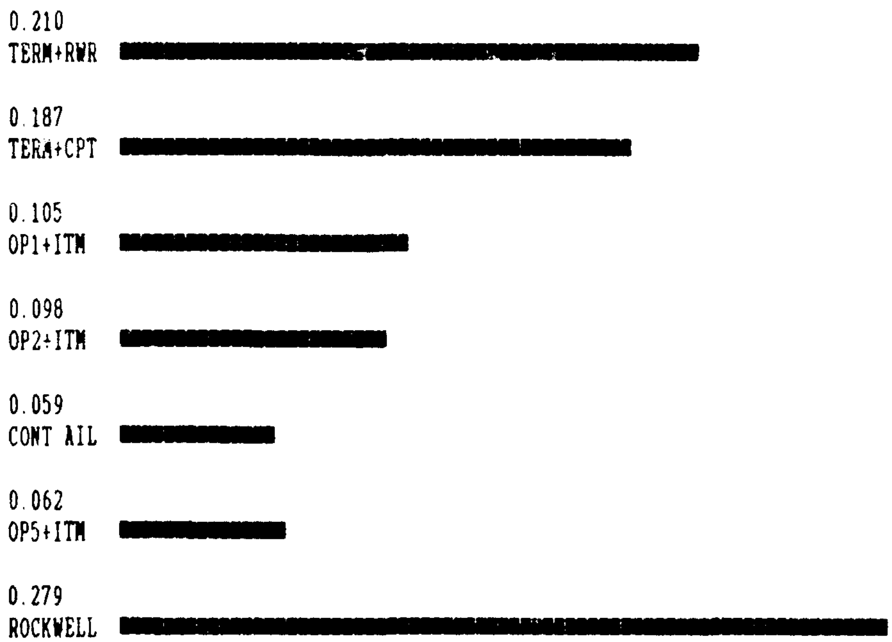
Figure 24. Pairwise Comparison Matrix
(Panels with respect to GOAL)

JUDGEMENTS AND PRIORITIES WITH RESPECT TO
CONTRACT < GOAL

	TERM+RWR	TERM+CPT	OP1+ITM	OP2+ITM	CONT AIL	OP5+ITM	ROCKWELL
TERM+RWR		1.2	3.1	2.2	3.0	3.4	(1.9)
TERM+CPT			2.0	2.9	2.7	3.1	(2.0)
OP1+ITM				1.4	1.8	2.1	(2.4)
OP2+ITM					2.0	2.3	(2.5)
CONT AIL						1.0	(5.2)
OP5+ITM							(2.5)
ROCKWELL							

Matrix entry indicates that ROW element is ...
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more PREFERABLE than COLUMN element
unless enclosed in parenthesis.

TERM+RWR : TERMINATE AIL + F-16 RWR
TERM+CPT : TERMINATE AIL + COMPETITION FOR NEW RWR
OP1+ITM : TERMINATE AIL + F-16 RWR + INCREASE TIME AND MONEY
OP2+ITM : TERMINATE AIL + COMPETITION FOR NEW RWR + INCREASE TIME AND MONEY
CONT AIL : CONTINUE WITH REMAINDER OF AIL CONTRACT
OP5+ITM : CONTINUE WITH AIL CONTRACT BUT INCREASE TIME AND MONEY
ROCKWELL : CONTINUE WITH AIL CONTRACT BUT MANAGED/BOUGHT BY ROCKWELL



INCONSISTENCY RATIO = 0.024

Figure 25. Pairwise Comparison Matrix (Options with respect to CONTRACT)

JUDGEMENTS AND PRIORITIES WITH RESPECT TO
SAC REQ < GOAL

	TERM+RWR	TERM+CPT	OP1+ITM	OP2+ITM	CONT AIL	OP5+ITM	ROCKWELL
TERM+RWR		4.0	1.0	3.0	2.0	2.0	4.0
TERM+CPT			4.0	(2.0)	2.0	1.0	2.0
OP1+ITM				1.0	2.0	(2.0)	1.0
OP2+ITM					3.0	2.0	2.0
CONT AIL						(3.0)	(2.0)
OP5+ITM							1.0
ROCKWELL							

Matrix entry indicates that ROW element is ...
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more PREFERABLE than COLUMN element
unless enclosed in parenthesis.

TERM+RWR : TERMINATE AIL + F-16 RWR
TERM+CPT : TERMINATE AIL + COMPETITION FOR NEW RWR
OP1+ITM : TERMINATE AIL + F-16 RWR + INCREASE TIME AND MONEY
OP2+ITM : TERMINATE AIL + COMPETITION FOR NEW RWR + INCREASE TIME AND MONEY
CONT AIL : CONTINUE WITH REMAINDER OF AIL CONTRACT
OP5+ITM : CONTINUE WITH AIL CONTRACT BUT INCREASE TIME AND MONEY
ROCKWELL : CONTINUE WITH AIL CONTRACT BUT MANAGED/BOUGHT BY ROCKWELL

INCONSISTENCY RATIO = 0.101

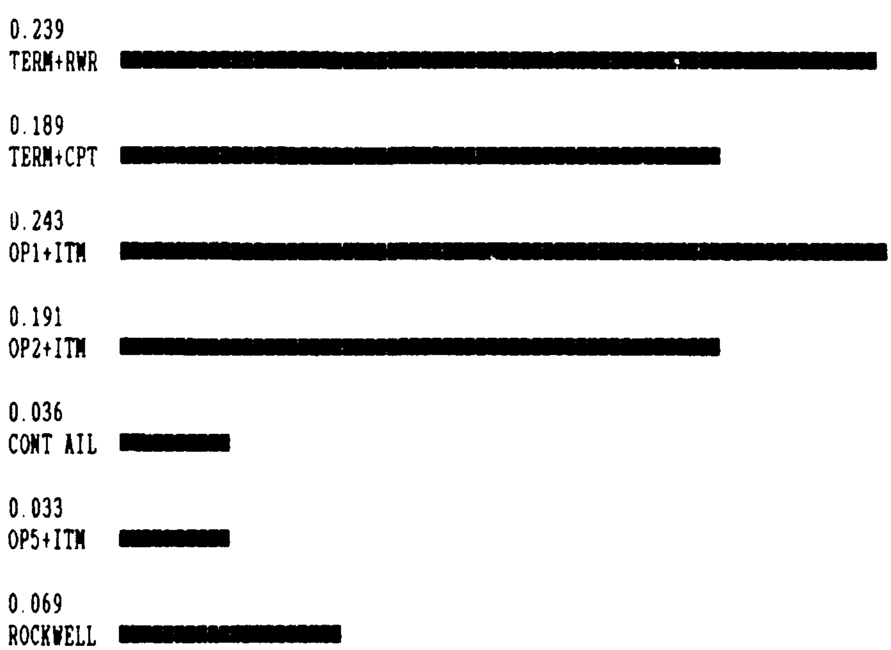
Figure 26. Pairwise Comparison Matrix (Options with respect to SAC REQ)

JUDGEMENTS AND PRIORITIES WITH RESPECT TO
TECH'NL < GOAL

	TERM+RWR	TERM+CPT	OP1+ITM	OP2+ITM	CONT AIL	OP5+ITM	ROCKWELL
TERM+RWR		1.6	(1.1)	1.2	5.7	6.3	4.4
TERM+CPT			(1.2)	(1.2)	5.2	6.1	3.8
OP1+ITM				1.7	5.3	6.2	4.1
OP2+ITM					4.8	5.9	3.5
CONT AIL						(1.3)	(2.4)
OP5+ITM							(3.6)
ROCKWELL							

Matrix entry indicates that ROW element is ...
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more PREFERABLE than COLUMN element
unless enclosed in parenthesis.

TERM+RWR : TERMINATE AIL + F-16 RWR
TERM+CPT : TERMINATE AIL + COMPETITION FOR NEW RWR
OP1+ITM : TERMINATE AIL + F-16 RWR + INCREASE TIME AND MONEY
OP2+ITM : TERMINATE AIL + COMPETITION FOR NEW RWR + INCREASE TIME AND MONEY
CONT AIL : CONTINUE WITH REMAINDER OF AIL CONTRACT
OP5+ITM : CONTINUE WITH AIL CONTRACT BUT INCREASE TIME AND MONEY
ROCKWELL : CONTINUE WITH AIL CONTRACT BUT MANAGED/BOUGHT BY ROCKWELL



INCONSISTENCY RATIO = 0.019

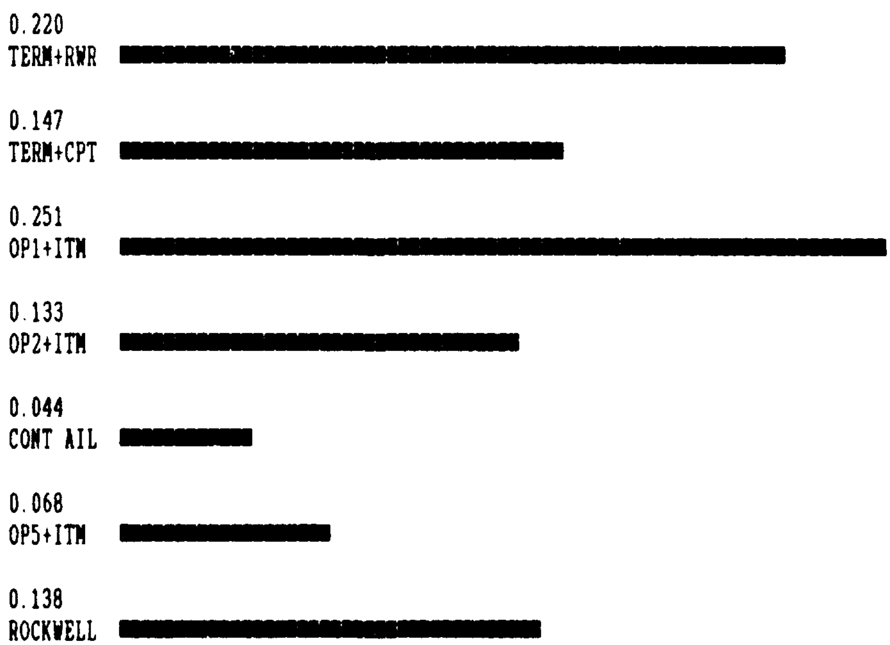
Figure 27. Pairwise Comparison Matrix
(Options with respect to TECH'NL)

JUDGEMENTS AND PRIORITIES WITH RESPECT TO
LOGISTIC < GOAL

	TERM+RWR	TERM+CPT	OP1+ITM	OP2+ITM	CONT AIL	OP5+ITM	ROCKWELL
TERM+RWR		3.2	(1.9)	1.5	3.5	2.7	2.2
TERM+CPT			(1.1)	1.0	2.9	2.1	1.9
OP1+ITM				3.3	3.3	2.7	2.2
OP2+ITM					2.8	2.3	1.6
CONT AIL						(2.5)	(5.5)
OP5+ITM							(4.2)
ROCKWELL							

Matrix entry indicates that ROW element is ...
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more PREFERABLE than COLUMN element
unless enclosed in parenthesis.

TERM+RWR : TERMINATE AIL + F-16 RWR
TERM+CPT : TERMINATE AIL + COMPETITION FOR NEW RWR
OP1+ITM : TERMINATE AIL + F-16 RWR + INCREASE TIME AND MONEY
OP2+ITM : TERMINATE AIL + COMPETITION FOR NEW RWR + INCREASE TIME AND MONEY
CONT AIL : CONTINUE WITH REMAINDER OF AIL CONTRACT
OP5+ITM : CONTINUE WITH AIL CONTRACT BUT INCREASE TIME AND MONEY
ROCKWELL : CONTINUE WITH AIL CONTRACT BUT MANAGED/BOUGHT BY ROCKWELL



INCONSISTENCY RATIO = 0.070

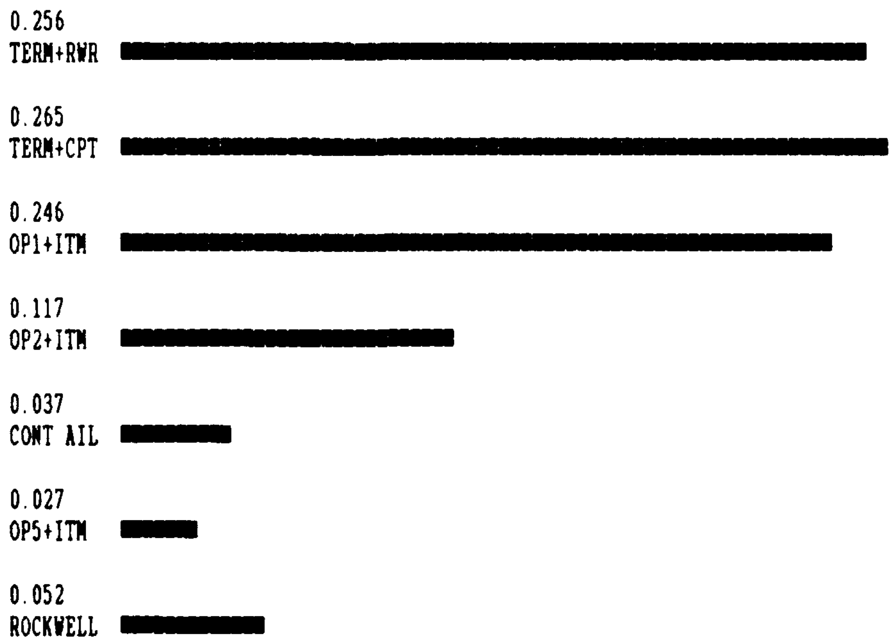
Figure 28. Pairwise Comparison Matrix
(Options with respect to LOGISTIC)

JUDGEMENTS AND PRIORITIES WITH RESPECT TO
COST < GOAL

	TERM+RWR	TERM+CPT	OP1+ITM	OP2+ITM	CONT AIL	OP5+ITM	ROCKWELL
TERM+RWR		(2.5)	2.5	2.8	9.0	9.0	3.0
TERM+CPT			(2.0)	3.0	9.0	9.0	3.0
OP1+ITM				3.0	9.0	9.0	3.0
OP2+ITM					7.0	7.0	2.0
CONT AIL						3.0	1.4
OP5+ITM							1.4
ROCKWELL							

Matrix entry indicates that ROW element is ...
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more PREFERABLE than COLUMN element
unless enclosed in parenthesis.

TERM+RWR : TERMINATE AIL + F-16 RWR
TERM+CPT : TERMINATE AIL + COMPETITION FOR NEW RWR
OP1+ITM : TERMINATE AIL + F-16 RWR + INCREASE TIME AND MONEY
OP2+ITM : TERMINATE AIL + COMPETITION FOR NEW RWR + INCREASE TIME AND MONEY
CONT AIL : CONTINUE WITH REMAINDER OF AIL CONTRACT
OP5+ITM : CONTINUE WITH AIL CONTRACT BUT INCREASE TIME AND MONEY
ROCKWELL : CONTINUE WITH AIL CONTRACT BUT MANAGED/BOUGHT BY ROCKWELL



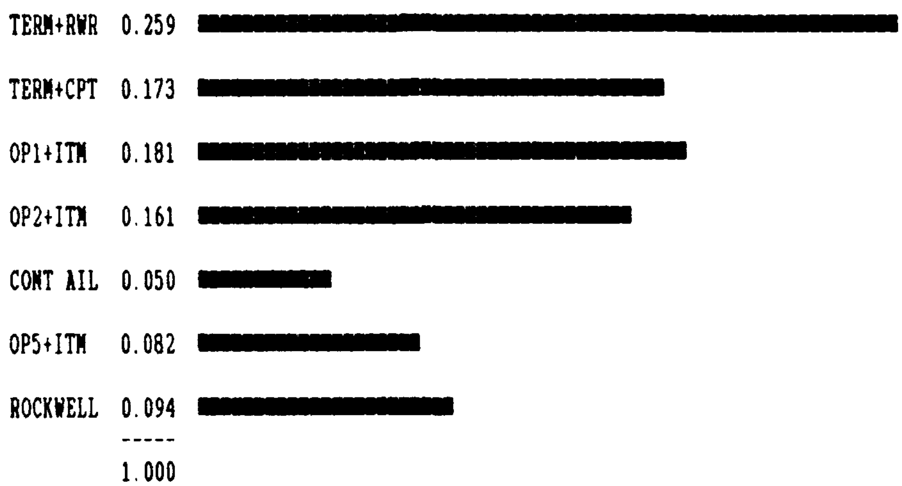
INCONSISTENCY RATIO = 0.119

Figure 29. Pairwise Comparison Matrix
(Options with respect to COST)

Select Option to Acquire Acceptable Avionics Package.

SYNTHESIS OF LEAF NODES WITH RESPECT TO GOAL

OVERALL INCONSISTENCY INDEX = 0.06



CONT AIL --- CONTINUE WITH REMAINDER OF AIL CONTRACT
OP1+ITM --- TERMINATE AIL + F-16 RWR + INCREASE TIME AND MONEY
OP2+ITM --- TERMINATE AIL + COMPETITION FOR NEW RWR + INCREASE TIME AND MONEY
OP5+ITM --- CONTINUE WITH AIL CONTRACT BUT INCREASE TIME AND MONEY
ROCKWELL --- CONTINUE WITH AIL CONTRACT BUT MANAGED/BOUGHT BY ROCKWELL
TERM+CPT --- TERMINATE AIL + COMPETITION FOR NEW RWR
TERM+RWR --- TERMINATE AIL + F-16 RWR

Figure 30. AHP Results for the B-1B Case

Case 3: Ground-Launched Cruise Missile (GLCM) Requirements

"Our test results show that the system does not meet user requirements," said Lt Col Robinson, the Air Force Operational Test and Evaluation Center (AFOTEC) test manager. Lt Col Jackson, the program manager for the Ground-Launched Cruise Missile (GLCM), knew this was coming and now was waiting for the "sparks to fly." It was May 1983 and Lt Col Jackson was attending the Air Force Systems Acquisition Review Council (AFSARC) Milestone III (production decision) meeting for his program at the Office of the Secretary of the Air Force. The AFSARC III meeting, chaired by the Secretary of the Air Force, was being held to discuss whether the GLCM, a major Air Force weapon system, was ready for production. The end result of the AFSARC meeting is normally the Secretary's approval or disapproval to start production. Prior to the AFOTEC briefing, Lt Col Jackson had briefed the Secretary on the GLCM program status and had told him that the GLCM would meet all specification requirements. AFOTEC disagreed (16). Why the disconnect? And why did it surface here, in front of the Secretary of the Air Force? These, of course, were questions the Secretary wanted answered ASAP!

GLCM History. The development of the Ground Launched Cruise Missile (GLCM) was a response to two threats facing Western Europe in the 1970s. The first threat came in 1977 when the Soviets began to deploy the SS-20 Intermediate Range Ballistic Missile (IRBM) (22:23). This mobile, 5000-

km-range missile could threaten all North Atlantic Treaty Organization (NATO) countries "from bases deep in the Soviet Union, where it was virtually immune to NATO conventional or nuclear strikes" (22:23). The SS-20 system was referred to as a Theater Nuclear Force (TNF). With a TNF as "secure" and "invulnerable" as the SS-20 apparently was, the Soviets use of their second threat became much more likely to succeed (22:23). That second threat was a "comprehensive, integrated system to attack and destroy the NATO TNF with conventional weapons," which the Soviets had been building up for years (22:23). The apparent Soviet strategy was to "develop the ability to destroy the NATO TNF, allowing them to use their huge conventional forces to conquer NATO" (22:23).

The members of the NATO alliance felt the pressure from these Soviet threats. Some members

> viewed with alarm not only the communist buildup but also the U.S. reaction or, better put, inaction. The war in Southeast Asia and the development of detente fed the lingering European suspicion that the United States could not be relied on. The former stripped men and machines from American forces stationed in Europe, while the latter restricted the Europeans from acquiring certain equipment and limited American cruise missile development. (30:201)

As a result of these pressures, in January 1979 "the leaders of Britain, France, Germany, and the United States agreed to President Carter's proposal to deploy Pershing II ballistic missiles and GLCMs to NATO" (30:201). This agreement to deploy the missiles was linked "with a simultaneous U.S. offer to begin negotiations with the Soviets on limiting

intermediate range missiles in Europe" resulting in a unanimous NATO approval of "this two-track proposal in December 1979" (30:201).

The NATO response to this dual Soviet threat was referred to as the Long-Range Intermediate Nuclear Forces (LRINF) modernization program. This program, which consisted of GLCM and the Pershing II ballistic missile, was designed to "provide a countervailing nuclear force with the prelaunch survivability to endure whatever conventional attacks the Soviets might launch" (22:23). Since NATO's strategy in Europe was to deter rather than fight a war, the GLCM and Pershing II seemed appropriate for the LRINF since both had a "range sufficient to hit critical Soviet targets but not for a first strike, since they cannot threaten the SS-20s east of the Urals" (22:23).

The GLCM Concept of Operations. The GLCM concept of operations, which was developed during 1976-78, was based on the U.S. Army's concept for the Pershing missile system. This concept called for using "fixed peacetime bases and small, covert field deployed units in wartime" (22:28). The concept for GLCM, however, did include three major deviations from the Pershing concept. First, the GLCM main operating bases (MOBs) were larger than the individual Pershing operating locations (22:28). This allowed more efficient use of security and support personnel. Second, MOB hardening was used to prevent being incapacitated by a "conventional surprise attack by aircraft or Spetsnaz"

(22:28). Spetsnaz is the name for small special Soviet teams of 10 to 12 men which can be a "potent force for both reconnaissance and attack" (22:23). The third difference was how the system was supported. Unlike the Pershing, the GLCM concept did not call for "deploying extensive support to the field" (22:28). Instead the GLCM maintained a "logistics connection to the MOB" (22:28). Although this practice introduced "potential vulnerability," this vulnerability was "minimized through operational procedures" (22:28). These procedures included providing rapid dispersal capability and minimization of wartime logistic support requirements (22:28). An additional unique aspect of the GLCM concept of operations was that of using "existing maintenance, security and missile-launch personnel with new GLCM specialist training to allow for a balance between the U.S.-based ballistic missile force and European GLCM assignments" (22:28). This aspect was desired because the Air Force wanted to minimize the use of "unusual technology" and thus avoid the requirement for "new maintenance and other skills" (22:28).

The GLCM System. The three basic hardware elements of the GLCM system are the Tomahawk missile, the transporter erector launcher (TEL), and the launch control center (LCC). Combinations of these three elements plus the logistics and operations support provided by the MOBs make up the GLCM system (22:31).

For off-MOB operations, the basic GLCM unit is a flight manned by 69 personnel and consists of two LCCs, four TELs, six M-925 supply trucks, two recovery vehicles, and 10 high-mobility multipurpose wheeled vehicles (HMMWVs or 'Hummers'). (22:29)

Figure 31 shows two LCCs and four TELs in the configuration of a dispersed flight. Of the 69 GLCM personnel, 44 make up a "combat trained security force" capable of defeating a Spetsnaz attack (22:29). "The remainder of the 69 personnel are maintenance and missile launch crew, plus a commander and medical technician, all equipped with M-16s to provide a final line of protection for the critical vehicles (TELs and LCCs)" (22:29). The three basic hardware elements are discussed in more detail below.

The Tomahawk Missile. Because the Soviet SS-20 was close to being deployed in 1976-77, when the GLCM concept was being developed, an initial operating capability (IOC) for the GLCM system was deemed extremely important. This meant that emphasis was put on utilizing existing or proven technology and subsystems as much as possible since development time was limited. This practice would also lower development costs, which was also desirable because of the GLCM's limited budget (22:28). This limited budget was "due to the austere U.S. defense budgets in the mid-1970s" (22:28). Because of the emphasis on early IOC and minimizing development costs, the use of the Navy-developed Tomahawk missile was directed (22:28). There were basically two advantages of using the Tomahawk. First, the missile's development had started in 1972 and its design had become

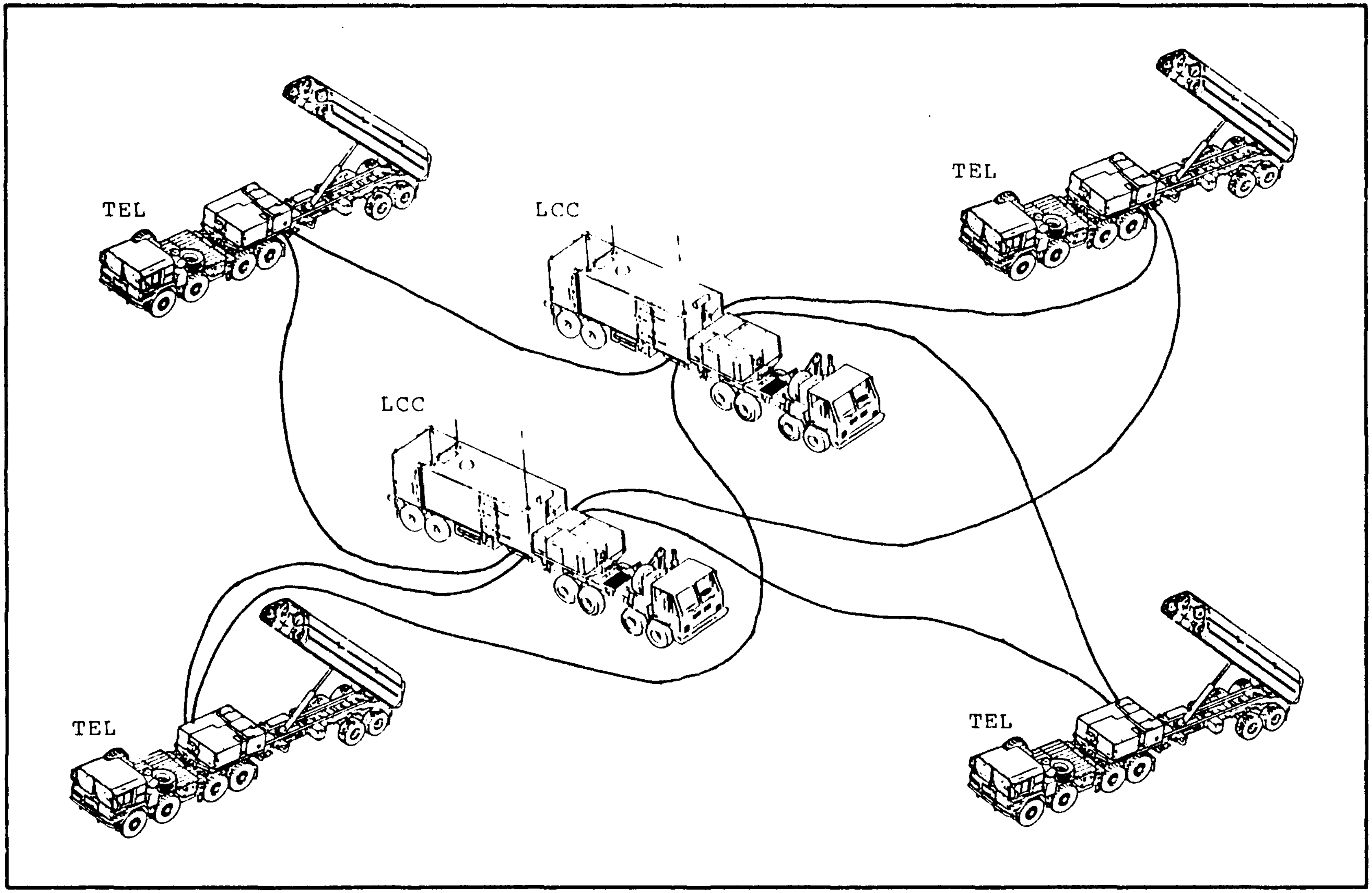


Figure 31. GLCM Flight (16)

relatively mature. The second advantage was that the missile was "compatible with tube launching," which would be the launching method used for GLCM. There was also a major disadvantage to using the Tomahawk, from the Air Force perspective. That disadvantage was that the Navy had already determined mission and performance requirements for the Tomahawk, and the Air Force had no opportunity to generate its own missile requirements. This caused the ground-based launching system design to be constrained by the Tomahawk design (23:158).

The Transporter Erector Launcher (TEL). The TEL was "designed to carry the Tomahawk missiles, elevate them to the proper launch angle and launch them" (23:31). Because the Tomahawk was originally designed to be launched from a submarine torpedo tube, it was a relatively "long, thin missile (21 inches in diameter and 252 inches in length)" (23:31). Because the missile was "long,"

> a standard missile mounting on a truck chassis would result in a vehicle too long to negotiate turns and corners in small European villages. A 'cab-over' mounting would violate a requirement that the TEL be transportable with missiles in C-130 and C-141 aircraft, which restricts vehicle height to 108 inches. The C-130 also limited the weight to approximately 36,000 pounds. For these reasons, the TEL was designed as an articulated tractor-trailer mounting four missiles. (23:31)

The Launch Control Center (LCC). "The LCC houses the launch equipment and communication gear, as well as the launch crew" (23:31). Within a GLCM flight there are four TELs (a total of 16 missiles) and two LCCs. Either LCC can

control any of the four TELs. Having two LCCs per flight not only provides redundancy to the communications system but also permits each flight to travel in two smaller convoys which improves the flight's survivability in the face of ambush and air attack (23:32). A key feature of the LCC is its ability to operate enroute (23:32). This feature adds to the LCC's level of survivability. Another LCC feature that adds to its survivability is its shelter that is "sealed against chemical, biological and radiological (CBR) contamination" (23:32).

"The key to GLCM survivability is mobility" (23:31). The two GLCM components providing the most mobility are the MAN tractor and the semitrailer. These two components are used to transport both the LCC and the TEL. The MAN tractors were "developed from the 8-by-8, high-mobility, 10-ton trucks provided to the German army by the MAN Company of West Germany" (23:31). The tractors are referred to as the M1013 and the M1014 and are used for the TEL and LCC, respectively. The semitrailers that carry the TEL and the LCC were designed by the U.S. Army Tank Automotive Command (TACOM) and are referred to as the M986 (for the TEL) and the M999 (for the LCC). The tractors and the semitrailers were designed for "high-mobility and off-road capability" (23:32).

There are three other major system features that contribute to system survivability. First, there are the 300-meter fiber optic cables (FOCs) that provide

communication links between the LCCs and the TELs (23:32). In addition, there is the armored forward equipment box (FEB) on the TELs which "contains that part of the weapon control system (WCS) controlled by the main WCS in the LCC, which controls and monitors all TEL and missile activities, including launch operations" (23:32). The third feature is self-contained power. Each of the TELs and LCCs contains its own nickel cadmium (Ni-Cad) batteries providing power while the flight is enroute and a power generator unit which is used after the flight has deployed in the field. Both the battery and generator are contained in the FEB (23:32).

> The combination of armor, self-contained power and [FOCs] greatly increases survivability. With self-contained power, each vehicle can be dispersed anywhere throughout the launch site while the 300-meter [FOCs] cables allow ample separation between vehicles. Wide vehicle spacing and armor combine to reduce the probability of a single attack destroying more than one vehicle. (23:32)

GLCM Requirements Problems. Earlier discussion addressed the fact that the development of the GLCM was accelerated due mainly to political pressure to minimize the time to meet IOC. Also mentioned earlier were the constraints on system design due to the directed use of the Tomahawk missile. With these ideas in mind, it may not be too surprising that various GLCM problems had been encountered by the time the AFSARC III meeting was held in May 1983.

Just four months prior to the AFSARC III meeting, in January 1983, a combined Development Test and Evaluation

(DT&E)/ Initial Operational Test and Evaluation (IOT&E) program had been completed and had surfaced various problems with the GLCM system. A˙ ₋nough the GLCM program was managed by the Joint Cruise Missile Program Office (JCMPO) in Washington, D.C., the program manager was an Air Force officer (Lt Col Jackson) and the implementing command was Air Force Systems Command (AFSC). The responsible test organization was AFOTEC, and the using command was the United States Air Forces in Europe (USAFE). AFSC disagreed with AFOTEC and USAFE with regard to the significance of some of the problems found in testing, the method for solving these problems, and whether these problems should delay the IOC date. Even though these disagreements were not being resolved as the program was briefed up the chain of command (below HQ USAF level), none of these command levels attempted to have the AFSARC III meeting rescheduled. This reluctance to delay the AFSARC III was due mainly to the pressure to meet IOC as scheduled (16). Thus these differences of opinion were voiced by Lt Col Robinson (AFOTEC) and Lt Col Jackson (AFSC) at AFSARC III. Below, some of the more significant problems discussed at the meeting are summarized.

Reliability. Reliability problems were found with both the missile (Tomahawk) and the power unit (PU) used to power the LCCs and the TELs while deployed in the field (16).

Missile. The main missile problem, according to AFOTEC, was that there was little flight test data (for the GLCM version of the Tomahawk) available to make reliability predictions. The GLCM program office relied on both GLCM flight tests and analogous (companion) test data from tests of other variants of the Tomahawk (i.e. Sea Launched Cruise Missile (SLCM)) to make reliability calculations. The program office predictions showed that reliability requirements would be met. The testers (AFOTEC), however, did not agree. At the time of the AFSARC III meeting, ten flight tests had been conducted on the GLCM version of the Tomahawk. Although eight of these ten tests were ruled successful, AFOTEC felt that these tests did not provide a good "independent" assessment because three of the ten were contractor conducted and the other seven were supported by the contractor. In addition, AFOTEC considered the use of the companion test data inappropriate because the different Tomahawk variants had different launch systems and in some cases different engines and guidance systems. AFOTEC was also concerned with a general downward trend over the previous three years in the success rate for flight tests of all Tomahawk variants. It was AFOTEC's opinion that more independent GLCM specific missile flight tests were needed to accurately predict whether the system would meet reliability requirements (16).

Power Unit (PU). The PU intended to be used to provide electricity for the GLCM system elements (LCCs and

TELs) was the MEP-404B diesel-powered generator. This was to be an improved version of the MEP-404A unit procured by the Army in the 1970s as a ground-based generator used for base support. Because of reliability problems with the MEP-404A, the Army had solicited the development of an improved MEP-404B. The MEP-404B was to have both improved electronics and an improved turbine (16).

Early in the GLCM program, the MEP-404B was expected to be available in 1982, which would allow its incorporation into the GLCM system in time for DT&E/IOT&E in January 1983 and for meeting IOC in December 1983. Unfortunately, it later became obvious that the new model would not be ready in time for IOT&E due mainly to problems with the new turbine design. Because of the importance of meeting the December 1983 IOC, the Air Force was forced to go ahead with IOT&E on schedule rather than delay it until the MEP-404B became available. This meant "well-used, cannibalized" MEP-404As would have to be used for testing purposes (16). The MEP-404A met GLCM power requirements but proved to be extremely unreliable. The MEP-404A performed with a mean-time-between-failure (MTBF) of only about 15 hours during the testing. This low PU MTBF was a problem in itself but what made it even worse was that a PU failure meant extensive "workarounds" would be required to provide auxiliary power (16). In the case of a PU failure, the Ni-Cad batteries, mentioned earlier, provided emergency power for the LCC. This emergency power could sustain launch

capability for approximately 45 minutes. The Ni-Cad batteries in the TELs, on the other hand, provided power for "standby monitor mode" only and could not sustain full power for launch. For this reason, a Hobart diesel auxiliary generator was used to back-up the MEP-404A during DT&E/IOT&E and was to be deployed with operational GLCM flights until the MEP-404B became available. Because of the inconvenience of transporting these auxiliary PUs and the significant set-up time required, this "workaround" was less than acceptable to the user (16).

For the purposes of the AFSARC III meeting, the program office chose to use MEP-404B reliability projections to predict a system reliability. As with the case of the missile tests, this practice was considered unacceptable by AFOTEC. AFOTEC contended that until the system could be tested with the MEP-404B, the reliability assessment should be based on testing of the system using the MEP-404A (16).

Communication System. The GLCM used a three-link system for communications between the dispersed GLCM flights and the MOBs. The three-link communication system consisted of a VHF, a UHF, and an HF link. The VHF link, a secure link, was the primary link between the dispersed flight and the MOB. The UHF link, also a secure link, was a secondary link to the MOB. This link utilized the FLAMING ARROW network which was used for control of European Command (EUCOM) forces. A dispersed flight would not normally contact EUCOM directly but instead would monitor the

network. If the MOB was "knocked out," the flight would set up its own command and would begin direct communication with EUCOM. The HF, an insecure link, was another secondary link utilizing the CEMETARY network which was used to control nuclear forces in Europe. Since transmitting on the insecure HF link could give away the flight's position, this link was only used when the other two were unavailable (16).

Several problems were found with the communication system. Probably the most significant was an operational problem with the VHF link. Because a VHF link operates on the "line-of-sight" principle, maintaining the link between a dispersed flight and the MOB was difficult. As was discussed earlier, the GLCM system concept called for dispersed units to "hide" in the field. This need for "hiding" contributed to the difficulty of maintaining the VHF link. The VHF link worked well in elevated terrain, but these locations were generally not good "hiding places." On the other hand, if the units were located in tree-covered valleys, the VHF link normally could not be maintained. GLCM's requirement for continuous radio contact made this communication system problem significant (16).

Other communication problems had to do with HF link. First, the HF required the use of a long antenna that had to be "tied down" and tended to break. In addition, interference between the transmitting antenna and the receiving antenna made it difficult to meet the requirement that the HF link be capable of receiving and transmitting

simultaneously. A simple solution to the interference problem was offered by the program office that called for using off-the-shelf equipment to "cut out" the receiver while transmitting. However, the user insisted simultaneous transmission and receiving was necessary even though the HF link was a second backup link (16).

Other Requirements Problems. Some other GLCM problems were also addressed at AFSARC III. There were several requirements that adversely affected system reliability that some considered "unrealistic". One such requirement was that the system be capable of worldwide operation in temperatures down to $-65^{\circ}F$. However, none of the European locations where the GLCM was to be operated ever experienced such low temperatures. The coldest of the locations was in the Netherlands where 30-year climatical data showed that the temperature never fell below $-20^{\circ}F$. This temperature requirement contributed to another problem. A requirement also existed that called for the use of a single fuel, diesel, in all GLCM vehicles. Using diesel, however, proved to be impossible in the $-65^{\circ}F$ environment. When tests were conducted in the climatic test facility at Eglin AFB, the diesel fuel froze before the temperature reached $-65^{\circ}F$. To solve this problem, arctic blends of diesel were tried but tests showed that certain additives in the arctic blends clogged fuel filters in the system, causing insufficient fuel flow to engines (16).

Another problem related to fuel was due to design of the system that fed fuel to the power units. The PU had its own built-in filter but no other filter existed in the line between fuel storage and the power unit. This meant the fuel was not filtered before entering the pump that moved the fuel from storage to the power unit. Therefore, the power unit received clean fuel but the pump did not. This caused pumps to fail at an unacceptable rate, contributing further to system unreliability. An additional problem with using diesel was discovered during testing. The diesel was found to promote algae growth which further contributed to filter and pump clogging (16).

AFSARC III Meeting. The GLCM problems just discussed indicate that the system was probably not quite ready to be deployed. As a result, the Secretary directed the GLCM team (AFSC, AFOTEC, and USAFE) to address all the issues discussed and come back in September 1983 for an AFSARC IIIB. He made it clear that the system would make the original IOC date, even if "workarounds" had to used to resolve deficiencies. AFOTEC and USAFE strongly objected to this approach (16). Lt Col Jackson looked forward to an "interesting" four months.

V. Summary

This chapter provides a summary of the results of the research, a conclusion, and recommendations for further research.

Research Summary

The purpose of this research was to generate up-to-date cases that could be used as teaching tools in both AFIT systems management courses and other university management courses. As a result of the research, three cases were written. These cases will expose students to the successes and failures of other managers and will, hopefully, better prepare students for dealing with the realities of "real world" systems management.

This research was conducted using the case writing methodology discussed in Chapter III. Three investigative questions guided the research. The resulting three cases each addressed one of these investigative questions as described below.

Question 1: What important issues are involved in the strategic planning process for weapon systems?

Case 1, "The Vanguard Strategic Planning Process," provides an Air Force example of an unsuccessful strategic planning process. The case brings out issues involved in strategic planning and also provides some insight into what makes a strategic planning process useful or not useful.

Question 2: What qualitative and quantitative methods of problem analysis and decision making are appropriate in managing weapon system programs?

Case 2, "The Analytic Hierarchy Process (AHP)," illustrates the application of a quantitative decision-making tool to an Air Force decision. The case describes the AHP and then illustrates how is was applied to a decision concerning the B-1B defensive avionics system. The student has the opportunity to evaluate the AHP and determine whether is was appropriately applied.

Question 3: How are weapon system functional and physical requirements identified and evaluated?

Case 3, "Ground-Launched Cruise Missile (GLCM) Requirements," describes how and why the GLCM system was acquired and how system requirements problems were addressed in preparation for production and deployment. The case gives students the opportunity to think about how system requirements should be identified and evaluated. It also demonstrates how complicating factors, such as politics, can make this process more difficult.

Conclusion and Recommendations

This research resulted in the creation of three cases that can be added to the database of systems management cases currently available for use in systems management classroom instruction. These cases address three important systems management issues, and will hopefully help future system managers deal with these issues. As discussed in Chapter I, it is important that the systems management case

database be maintained in an up-to-date state. This means continually providing new cases that reflect the use of current technology, theory, and management thought. Cases pertaining to the following subject areas would also help keep the systems management case database current. Further case research in these areas is recommended.

(1) Quantitative or qualitative decision-making tools (other than the AHP)

(2) Government/defense contractor relations

(3) Source selection

(4) Application of Expert Systems (ES)/Decision Support Systems (DSS) in systems management

(5) Managing in government laboratories.

Appendix A: Abbreviations and Acronyms

AF = Air Force

AFCMD = Air Force Contract Management Division

AFOTEC = Air Force Operational Test and Evaluation Center

AFSARC = Air Force System Acquisition Review Council

AFSC = Air Force Systems Command

AFSPACECOM = Air Force Space Command

AHP = Analytic Hierarchy Process

ASD = Aeronautical Systems Division

ATC = Air Training Command

CBR = chemical, biological, and radiological

CI = consistency index

CR = consistency ratio

DCS = Deputy Chief of Staff

DG = Defense Guidance

DOD = Department of Defense

DRU = Direct Reporting Unit

DT&E = development test and evaluation

ECM = electronic countermeasures

EUCOM = European Command

FEB = forward equipment box

FOC = fiber optic cable

FYDP = Five Year Defense Program

GA = Global Assessment

GLCM = Ground-Launched Cruise Missile

IOC = initial operating capability

IOT&E = initial operational test and evaluation

IRBM = Intermediate-Range Ballistic Missile

JCMPO = Joint Cruise Missile Program Office

JCS = Joint Chiefs of Staff

JSPD = Joint Strategic Planning Document

LCC = launch control center

LRINF = Long-Range Intermediate Nuclear Forces

MAC = Military Airlift Command

MAJCOM = major command

MOB = main operating base

MTBF = mean-time-between-failure

NATO = North Atlantic Treaty Organization

NSC = National Security Council

OSD = Office of the Secretary of Defense

PACAF = Pacific Air Forces

PGM = Planning Guidance Memorandum

POM = Program Objective Memorandum

PPBS = Planning, Programming, and Budgeting System

PU = power unit

RDT&E = Research, Development, Test, and Evaluation

RFP = Request for Proposal

RI = random consistency indicator

RWR = radar warning receiver

S&T = science and technology

SAC = Strategic Air Command

SECDEF = Secretary of Defense

SLCM = Sea-Launched Cruise Missile

SOA - Separate Operating Agency

SON - Statement of Operational Need

SPA = Strategy and Policy Assessment

SPO - System Program Office

TAC - Tactical Air Command

TACOM - U.S. Army Tank Automotive Command

TEL - transporter erector launcher

TNF = Theater Nuclear Force

TOA = Total Obligation Authority

USAFE - United States Air Forces in Europe

WCS - weapon control system

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OH 45433-6583

REPLY TO ATTN OF: LSY

SUBJECT: Vanguard Strategic Planning Case

TO: AFIT/LSG (Capt Weishoff) FJW
AFIT/PA
<u>IN TURN</u>

1. Enclosed is a case entitled, "The Vanguard Strategic Planning Process." This case is based on the experiences of Capt Fredric J. Weishoff, AFIT/LSG, and was written as part of a graduate thesis research project. Our intention is to use the case as a teaching tool for Air Force Institute of Technology (AFIT) graduate courses and any courses offered by other universities interested in using the case.

2. Request AFIT/LSG (Capt Weishoff) review the case for technical accuracy and indicate any necessary changes directly on the attached copy of the case or attach comments under separate cover if necessary.

3. Request AFIT/PA approve release of the case for the purposes discussed in paragraph 1. above.

4. Please expedite your review. This case forms an integral part of Capt Roberts' graduate thesis, which must be completed by 14 August 1990. Thank you for your cooperation. Any questions regarding this request should be directed to Capt Rob Roberts, AFIT/LSG, at 253-0578 (home) or to the undersigned at 53355.

Curtis R Cook

CURTIS R. COOK, Lt Col, USAF
Head, Department of System
  Acquisition Management
School of Systems and Logistics

1st Ind, AFIT/PA 31 Jul 90

TO: LSG

Approved/~~disapproved~~ for Public Release IAW AFR 190-1.
Log Number: 90-07-24

Janetta S. Brown

FOR HARRIET D. MOULTRIE, Capt, USAF
Director, Office of Public Affairs

STRENGTH THROUGH KNOWLEDGE

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OH 45433-6583

REPLY TO ATTN OF: LSY

SUBJECT: Analytical Hierarchy Process (AHP) Case

TO: ASD/ENSSE (Capt Hearrell)
AFIT/PA
IN TURN

1. Enclosed is a case entitled, "The Analytical Hierarchy Process (AHP)." This case is based on the experiences of Capt Jeffrey D. Hearrell, ASD/ENSSE, and was written as part of a graduate thesis research project. Our intention is to use the case as a teaching tool for Air Force Institute of Technology (AFIT) graduate courses and any courses offered by other universities interested in using the case.

2. Request ASD/ENSSE (Capt Hearrell) review the case for technical accuracy and indicate any necessary changes directly on the attached copy of the case or attach comments under separate cover if necessary.

3. Request AFIT/PA approve release of the case for the purposes discussed in paragraph 1. above.

4. Please expedite your review. This case forms an integral part of Capt Roberts' graduate thesis, which must be completed by 14 August 1990. Thank you for your cooperation. Any questions regarding this request should be directed to Capt Rob Roberts, AFIT/LSG, at 253-0578 (home) or to the undersigned at 53355.

Curtis R Cook

CURTIS R. COOK, Lt Col, USAF
Head, Department of System
Acquisition Management
School of Systems and Logistics

1st Ind, AFIT/PA 9 Aug 90

TO: LSY

Approved/~~disapproved~~ for Public Release IAW AFR 190-1.
Log Number: 90-07-25

Janett S. Brown

FOR HARRIET D. MOULTRIE, Capt, USAF
Director, Office of Public Affairs

STRENGTH THROUGH KNOWLEDGE

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OH 45433-6583

23 JUL 1990

REPLY TO ATTN OF: LSY

SUBJECT: Ground-Launched Cruise Missile (GLCM) Case

TO: ASD/VC (Lt ~~Col~~ Hemmig)
AFIT/PA
IN TURN

1. Enclosed is a case entitled, "Ground-Launched Cruise Missile (GLCM) Requirements." This case is based on the experiences of Lt Col Floyd G. Hemmig, ASD/VC, and was written as part of a graduate thesis research project. Our intention is to use the case as a teaching tool for Air Force Institute of Technology (AFIT) graduate courses and any courses offered by other universities interested in using the case.

2. Request ASD/VC (Lt Col Hemmig) review the case for technical accuracy and indicate any necessary changes directly on the attached copy of the case or attach comments under separate cover if necessary.

3. Request AFIT/PA approve release of the case for the purposes discussed in paragraph 1. above.

4. Please expedite your review. This case forms an integral part of Capt Roberts' graduate thesis, which must be completed by 14 August 1990. Thank you for your cooperation. Any questions regarding this request should be directed to Capt Rob Roberts, AFIT/LSG, at 253-0578 (home) or to the undersigned at 53355.

Curtis R Cook

CURTIS R. COOK, Lt Col, USAF
Head, Department of System
Acquisition Management
School of Systems and Logistics

1st Ind, AFIT/PA

08 AUG 1990

TO: LSY

Approved/~~disapproved~~ for Public Release IAW AFR 190-1.
Log Number: 90-07-26

Janett S. Brown

FOR HARRIET D. MOULTRIE, Capt, USAF
Director, Office of Public Affairs

STRENGTH THROUGH KNOWLEDGE

Bibliography

1. "Air Force Space Command," Air Force Magazine, 72: 67-68 (May 1989).

2. "Air Force Systems Command," Air Force Magazine, 72: 68-70 (May 1989).

3. "Ai Training Command," Air Force Magazine, 72: 70-71 (May 1989).

4. Aldridge, James F. et al. "History of the Aeronautical Systems Division, January - December 1986, Volume I - Narrative." History Office, Aeronautical Systems Division, Air Force Systems Command. Wright-Patterson AFB OH, 1986.

5. Argyris, Chris. "Some Limitations of the Case Method: Experiences in a Management Development Program," Academy of Management Review, 5: 291-298 (April 1980).

6. Berger, Michael A. "In Defense of the Case Method: A Reply to Argyris," Academy of Management Review, 8: 329-333 (April 1983).

7. The Biennial Planning, Programming and Budgeting System. BPPBS Primer. Directorate of Programs & Evaluation, DCS/Programs & Resources, Department of the Air Force, Washington DC, January 1989.

8. Bocker, Franz. "Is Case Teaching More Effective than Lecture Teaching in Business Administration? An Exploratory Analysis," Interfaces, 17: 64-71 (September-October 1987).

9. Charan, Ram. "Classroom Techniques in Teaching by the Case Method," Academy of Management Review, 1: 116-123 (July 1976).

10. Croxton, Frederick E. et al. Applied General Statistics. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1967.

11. Department of the Air Force. Basic Aerospace Doctrine of the United States. AFM 1-1. Washington: Hq USAF, 1 October 1984.

12. Department of the Air Force. Budget: The Air Force Budget Process. AFP 172-4. Washington: Hq USAF, 1 October 1984.

13. Griffiths, Dave and Zachary Schiller. "The B-1B: Haste is Making Waste," Business Week: 29 (February 9, 1987).

14. Hearrell, Capt Jeffrey D. "Evaluation of the B-1 Defensive Avionics Prograr. by the Analytical Hierarchy Process." Report to the B-1B System Program Office. ASD/EMSSE, Wright-Patterson AFB OH, March 1989.

15. -----, Systems Effectiveness Engineer. Personal interviews. ASD/ENSSE, Wright-Patterson AFB OH, 27 April through 22 June 1990.

16. Hemmig, Lt Col Floyd G., Deputy Program Director for Advanced Cruise Missile SPO. Personal interviews. ASD/VC, Wright-Patterson AFB OH, 13 June through 29 June 1990.

17. Leenders, Michiel R. and James A. Erskine. Case Research: The Case Writing Process (Third Edition). London, Ontario: Research and Publications Division, School of Business Administration, The University of Western Ontario, 1989.

18. -----. The Normal Process for Writing Cases. Case Writing Workshop Pamphlet. School of Business Administration, The University of Western Ontario, London, Ontario, Canada, undated.

19. "Military Airlift Command," Air Force Magazine, 72: 76-80 (May 1989).

20. O'Dell, William F. "And Once Again... The Case Method Revisited," Collegiate News and Views, 29: 17-21 (Winter 1975-76).

21. "Pacific Air Forces," Air Force Magazine, 72: 83-84 (May 1989).

22. Rogers, Lt Col Michael E. "The GLCM - A Study in Survivability Design," Defense Science, 8: 23-29 (March 1989).

23. -----. "The GLCM - A Study in Survivability Design (Part II)," Defense Science, 8: 31-35 (May 1989).

24. Saaty, Thomas L. Decision Making for Leaders. Belmont, California: Wadsworth, Inc., 1982.

25. "Strategic Air Command," Air Force Magazine, 72: 87-88 (May 1989).

26. "Tactical Air Command," Air Force Magazine, 72: 90-94 (May 1989).

27. "United States Air Forces in Europe," Air Force Magazine, 72: 97-99 (May 1989).

28. Weishoff, Capt Fredric J. II, AFIT Graduate Student. Personnel Interviews. AFIT/LSG, Wright-Patterson AFB OH, 11 January through 23 March 1990.

29. -----. "A Study to Determine the Effectiveness of the Strategic Planning Process of the Air Force." Thesis Research Proposal. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1989.

30. Werrell, Kenneth P. The Evolution of the Cruise Missile. Maxwell AFB, Alabama: Air University (AU), Air University Press, 1985.

31. Young, Susan H. H. "Gallery of USAF Weapons," Air Force Magazine, 72: 133-150 (May 1989).

Vita

Captain Julian R. Roberts, Jr[redacted] He graduated from Edgewater High School in Orlando, Florida in 1979 and attended the University of Central Florida, graduating with a Bachelor of Science in Engineering (specialty: Mechanical Engineering) in April 1984. In January 1985, he entered the Air Force as an Officer Trainee at the Officer's Training School (OTS) at Lackland AFB, Texas. Upon graduation from OTS in April 1985, he received his commission and served his first tour of duty at Aeronautical Systems Division (ASD), Wright-Patterson AFB, Ohio. His duty began at ASD in April 1985, where he served as Financial Manager and Cost Analyst for various acquisition programs managed by the Deputy for Airlift and Trainer Systems. In November 1987, he was reassigned as a C-5B Training Systems Program Manager in the Systems Program Office. There he was responsible for managing two C-5B maintenance trainer acquisition projects until entering the School of Systems and Logistics, Air Force Institute of Technology, in May 1989.

[redacted]

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1990

3. REPORT TYPE AND DATES COVERED
Master's Thesis

4. TITLE AND SUBTITLE
A DATABASE OF SYSTEMS MANAGEMENT CASES

5. FUNDING NUMBERS

6. AUTHOR(S)
Julian R. Roberts, Jr., Captain, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology, WPAFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GSM/LSY/90S-22

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The purpose of this study was to generate a collection of systems management cases that would help graduate students and others learn the nuances of managing complexity. The cases will help ensure the systems management case database is up-to-date, and reflects current technology, theory, and management thought. The research was based on a case writing methodology espoused by Leenders and Erskine in their book entitled Case Research: The Case Writing Process. Three comprehensive new cases were created: "The Vanguard Strategic Planning Process," which addresses issues concerning strategic planning in the Air Force; "The Analytic Hierarchy Process (AHP)," which describes a quantitative decision-making tool called the AHP and how it can be applied; and "Ground-Launched Cruise Missile (GLCM) Requirements," which describes how and why the GLCM system was acquired and how system requirements problems were addressed.

14. SUBJECT TERMS
Systems Management, Defense Planning, Decision Theory, Acquisition Management, Case Studies, Cruise Missiles, Strategic Planning

15. NUMBER OF PAGES
117

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL